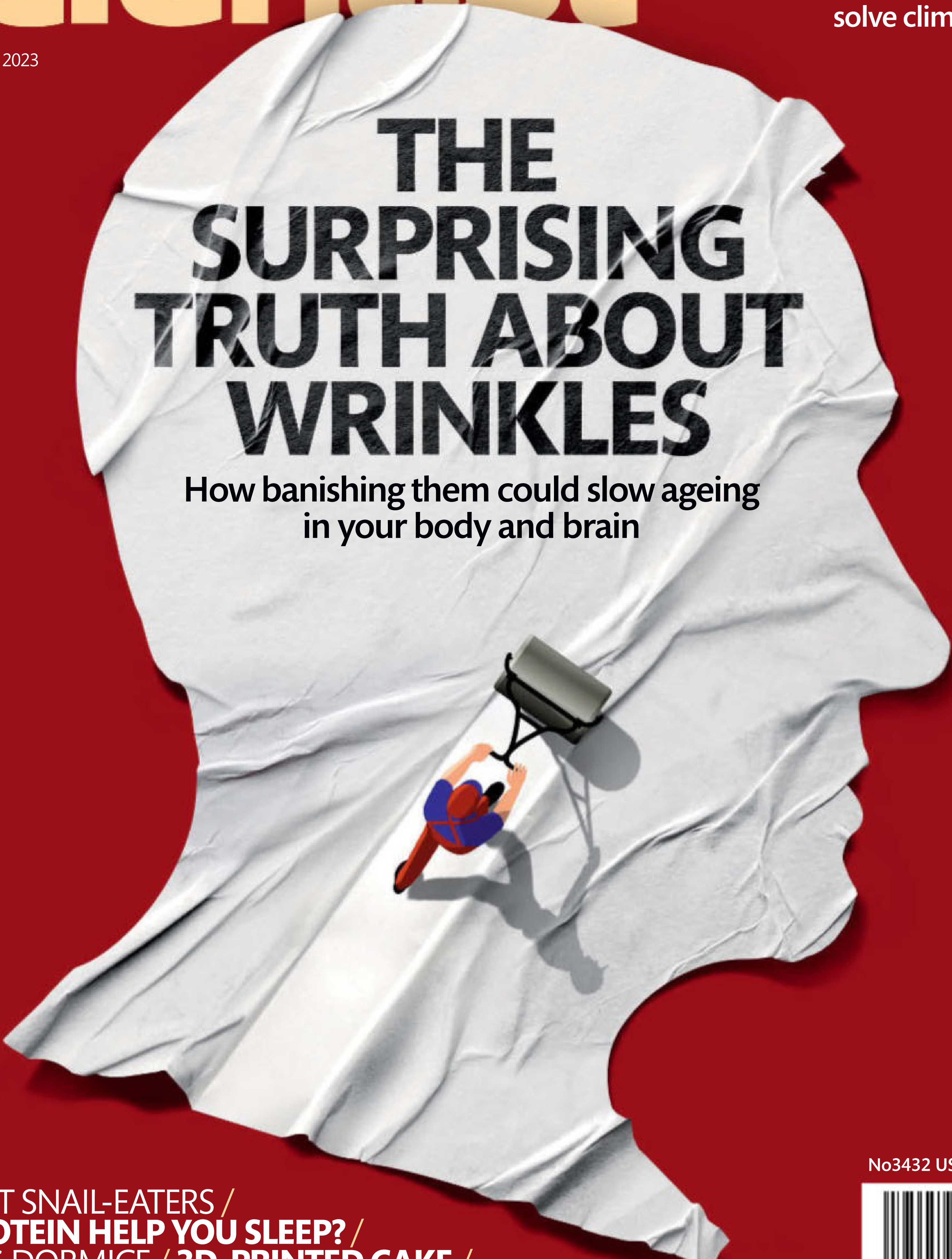
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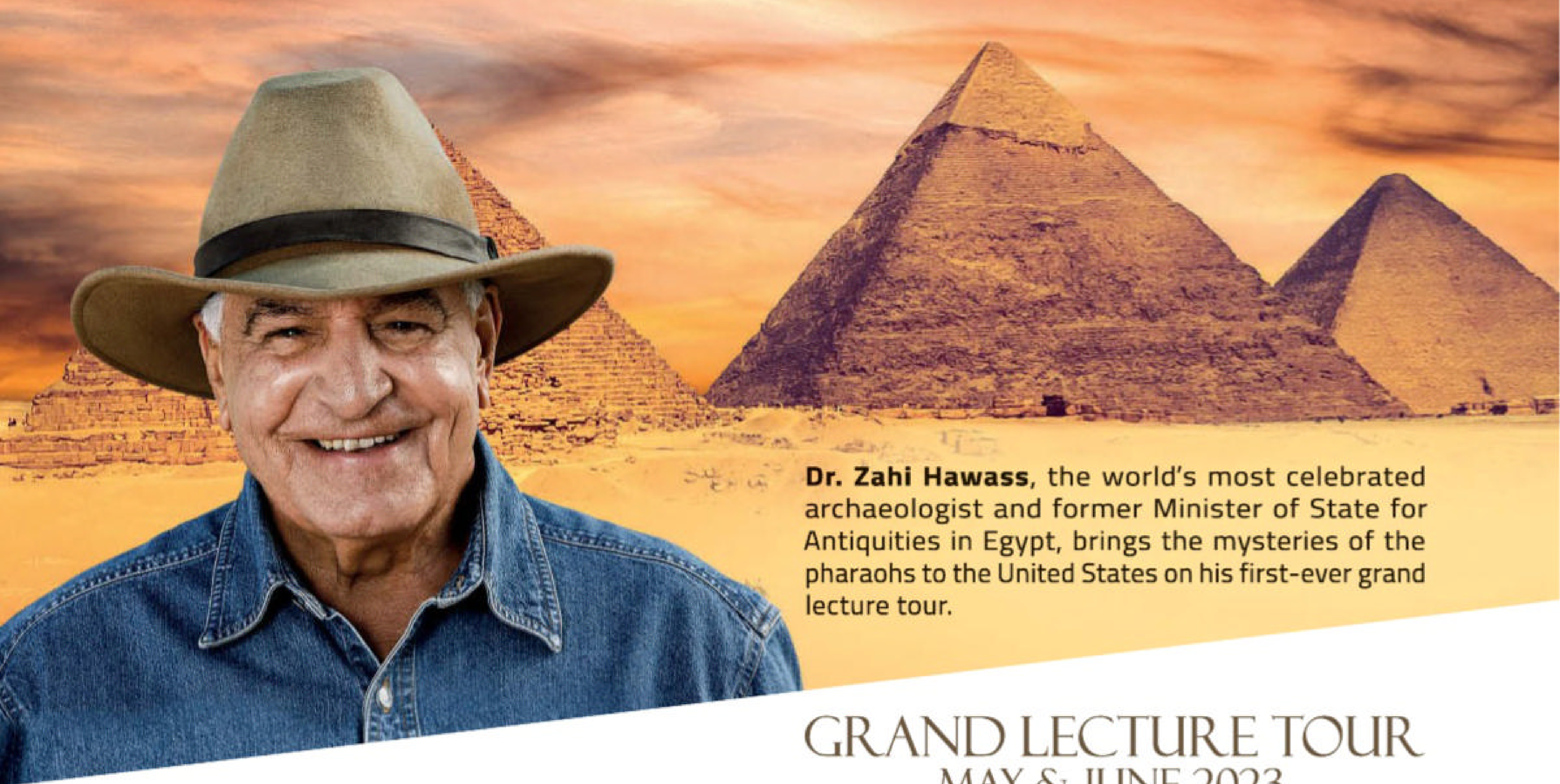
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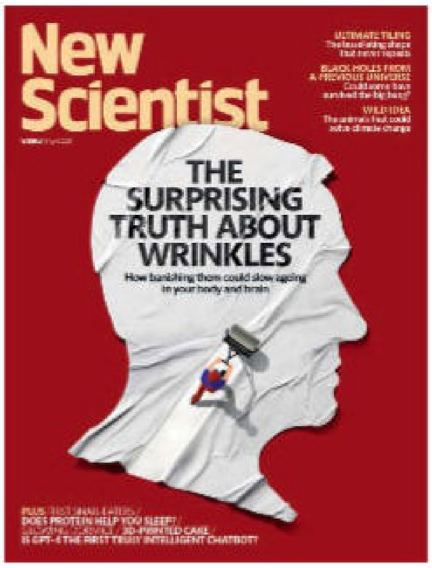
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LOST GOLDEN CITY – PYRAMIDS – MUMMIES – KING TUT – CLEOPATRA – & MORE!

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How banishing them could slow ageing in your body and brain



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YUSUF WAHIL/AFP VIA GETTY IMAGES

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Virtual event

Fermilab: Solving the mysteries of matter and energy, space and time

Join Fermilab senior scientist Don Lincoln as he explains what the particle physics facility in Illinois has taught us about our universe. Major discoveries made at the lab include the top and bottom quarks – and its future work might be critical for a "theory of everything". Online on 4 April at 6pm BST/ 1pm EDT. Tickets are £16.

newscientist.com/events

Tour

Ancient caves, human origins: Northern Spain

Mix modern and ancient culture on a trip through northern Spain. Accompanied by *New Scientist*'s editor in chief Emily Wilson, you will explore caves rich in art created 40,000 years ago, then visit the Guggenheim Museum Bilbao to enjoy some world-class contemporary pieces. The seven-day tour starts on 13 June and costs £2999.

newscientist.com/tours

Podcast

Weekly

Following the latest report from the Intergovernmental Panel on Climate Change, podcast editor Rowan Hooper and the team explain why we must do more to tackle global warming. Plus, there is news that quantum life might exist on Saturn's moon Titan. And, in a bonus episode, Rowan reports on polar bears and more from Svalbard, Norway.

newscientist.com/nspod



JESUS DE FUENSANTA/SHUTTERSTOCK

Stone Age culture View 40,000-year-old art in northern Spain



PAULETTE SINCLAIR/ALAMY

Bear country How will Arctic animals adapt to melting glaciers?

Video

3D-printed food

This week, watch scientists creating a slice of cheesecake using a 3D printer. The strange dessert was made from several pastes concocted from different ingredients, including crackers, strawberry jam, banana puree and frosting, and it was "cooked" using a laser. According to its creators, it has a taste quite unlike that of a conventional cheesecake.

youtube.com/newscientist

Newsletter

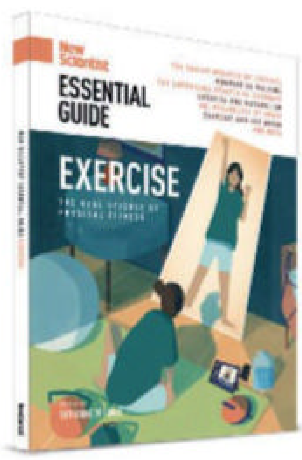
Wild Wild Life

We can learn a lot about how large, multicellular organisms evolved by studying single-celled life forms that sometimes cluster together and cooperate, writes news and digital director Penny Sarchet. The latest example of this behaviour is an organism called *Stentor coeruleus*, which feeds more efficiently in groups.

newscientist.com/ wild-wild-life

Newsletter

"If cells had never started cooperating, our planet would never have evolved animals and plants"



Essential guide

Exercise is the best medicine. It keeps our bodies and minds in prime condition and adds years to our lives. But why do so few of us get enough? This *New Scientist Essential Guide* offers some clues. Available to download in the *New Scientist* app or to purchase in print from our shop.

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Not just skin deep

An industry founded on beauty ideals could be due a makeover

WRINKLES are big business. Around the world, people are living longer and populations are ageing. Most people can expect to make it to their 60s at least. As the number of older people increases, so does the desire to cover up one of ageing's most prominent signs. Recent market research found that consumers in the US spent $9.1 billion on anti-wrinkle creams and moisturisers in 2021 and will be spending nearly $13 billion in 2027.

That expenditure is essentially a vanity project driven by a desire or pressure to look younger. There is no shortage of options, often at astronomical prices. However, there is a growing case for that bill to be picked up by healthcare providers and private insurers.

Wrinkles are much more than a cosmetic problem. As we report in our cover story on page 38, there is growing evidence that they aren't just a rough indicator of our biological age, but are also a key driver of ageing. Wrinkled skin appears to be toxic, pumping out compounds that accelerate age-related changes throughout our brains and bodies.

"Wrinkles aren't just an indicator of our biological age, but could be a key driver of ageing"

That makes sense when you consider that skin is on the front line. Because it is exposed to sunlight, pollutants and other insults, it ages faster than the rest of our bodies, and then seems to drag the rest of our bodies with it. Ageing is also a leading cause of illness and, ultimately, death. By the time we are in our 60s, most of us have at least one age-related disease, and they accumulate exponentially from then on at huge cost to the health services. Those costs are only going to rise as the population gets older.

One goal of the recent surge in anti-ageing research is to extend healthspan – in other words, to delay the development of age-related diseases and compress their cascading onset into a few years right at the end of life. It looks as though tackling the causes of wrinkling offers a fairly simple way of achieving this, thereby saving taxpayers billions. And if we all end up looking younger as a result, then that is a wrinkle in the story worth celebrating. ■

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TREVOR MAHLMANN/RELATIVITY SPACE/ZUMA WIRE/SHUTTERSTOCK

Space

3D-printed rocket blasts off

These are the engines of Terran 1, the world's first 3D-printed rocket – around 85 per cent of the vehicle was built using the additive manufacturing process. Created by Relativity Space, which aims to one day build a rocket that is 95 per cent 3D printed, Terran 1 launched from Cape Canaveral in Florida on 23 March, though it failed to reach orbit.

Climate change

Rewilding could be a big climate fix

Protecting or expanding wildlife populations can make a large contribution to carbon removal

Christa Lesté-Lasserre

RESTORING the populations of just a few important groups of animals could help capture huge amounts of carbon from the air and thereby play a role in limiting global warming.

Climate change research has emphasised the importance of vast forests and seagrass meadows as the most efficient way of storing carbon. But bison, elephants, whales, sharks and other massive wild animals also store carbon in their bodies, while promoting tree and seagrass growth, preventing carbon-releasing wildfires and packing down ice and soil to keep carbon in the ground, says Oswald Schmitz at Yale University.

"There's been scepticism in the scientific community that animals matter, because if you just do the accounting, they'd say animals don't make up much of the carbon on the planet, so they can't be important," he says. "What we're doing is connecting the dots, showing that animals – despite their lack of abundance – have an outsized role because of the multiplier effects that they create."

To keep the average global temperature from rising more than 1.5°C above its pre-industrial level, scientists estimate that we need to remove 6.5 gigatonnes of carbon dioxide per year from the atmosphere until 2100. Current models that focus on protecting and restoring forest, wetland, coastal and grassland ecosystems would fall short by an estimated 0.5 to 1.5 gigatonnes per year, according to Schmitz.

Grey wolves can increase carbon removal by keeping herbivores in check



TIM FITZHARRIS/MINDEN PICTURES/ALAMY

He and his colleagues reviewed data from previous publications about the environmental effects of dozens of kinds of wild animals, including dispersing seeds, trampling, carbon cycling, feeding behaviour, hunting behaviour and methane production.

They determined that we could theoretically meet the planet's carbon-reduction goals by protecting six groups of animals and expanding another three. The populations of reef sharks, grey wolves, wildebeest, sea otters, musk oxen and ocean fish need to be maintained at current levels. We would also need populations of at least 500,000 African forest elephants, 2 million American bison and 188,000 baleen whales in the Southern Ocean (*Nature Climate Change*, doi.org/j37t). Collectively, these populations could help capture approximately 6.41 gigatonnes of carbon dioxide annually, says Schmitz.

He says these animal populations can rebound quickly if the right conditions are in place, but we would need to return vast areas of farmland to nature.

"Instead of being cattle ranchers, let's think about being carbon ranchers," he says. "Let's bring the bison back and actually pay the ranchers for the carbon that they store rather than the meat produced by cattle."

However, the findings don't provide enough evidence for policy recommendations, says Yadvinder Malhi at the University of Oxford. "The science is not yet robust enough and the timescales involved in many cases are too slow given the urgency of the climate crisis," he says. ▮

Solar system

Astronauts on the moon could mine water from glass

TINY glass beads on the moon formed by meteoroid impacts might collectively contain as much water as there is in ice near the lunar poles, and could be harvested for water by future expeditions to the moon.

Mahesh Anand at the Open University in Milton Keynes, UK, and his colleagues analysed samples returned to Earth by China's Chang'e-5 lunar probe and found glass beads, known as spherules, that are formed in the extremely hot aftermath of meteoroids hitting the surface of the moon.

Using microscopes and spectroscopy to analyse the glass beads, the team found they contained water with the same hydrogen isotopes – atoms of the same element that differ by the number of neutrons they contain – as those found in charged particles ejected by the sun.

Previous research has shown that spherules can contain oxygen, so the researchers suspect that hydrogen from the sun combined with this oxygen to make water.

The moon is constantly being pummelled by meteoroids because it has no atmosphere, meaning these beads should be scattered across its surface. The team estimates that there could be around 300 billion tonnes of water stored within them. That is comparable with the amount of water ice on the moon in permanently shadowed craters near the poles, and is potentially much easier to access (*Nature Geoscience*, doi.org/j39f).

"I think it is going to be of interest for those who are planning to actually send missions to the moon"

"This is not only scientifically interesting, but I think it is going to be of quite some interest for those who are planning to actually send missions to the moon, to extract resources such as water for enabling more sustainable and longer-term exploration," says Anand. "It shouldn't be too difficult to actually heat this material and expect that some water would be released." ▮

Alex Wilkins

Archaeology

Ancient humans got a taste for roasted snails very early on

Carolyn Wilke

BROKEN bits of shell found in a cave in Africa have given researchers the earliest evidence for prehistoric people roasting and eating snails.

Excavations at Border Cave in South Africa, near its boundary with Eswatini, turned up the shell fragments in layers of dirt dating from 70,000 to 170,000 years ago. Other studies have pointed to snail consumption at sites in Europe around 30,000 years ago and in Africa around 40,000 years ago.

"There is a huge gap from that to our findings," says Marine Wojcieszak, who led the new work while at the University of the Witwatersrand in Johannesburg, South Africa.

The shell scraps came in a spectrum of colours, so Wojcieszak and her colleagues wondered if cooking had changed their hue.

The researchers heated pieces of modern snail shell in a furnace and compared them with the ancient remains. This showed that the prehistoric shells had been warmed to varying degrees, says Wojcieszak, suggesting that snails in their shells may have been placed on coals where they roasted unevenly (*Quaternary Science Reviews*, doi.org/j3x4). However, the experiments don't rule out the possibility that live snails were heated by accident, she says.

A modern snail shell used in experiments to determine the effects of cooking

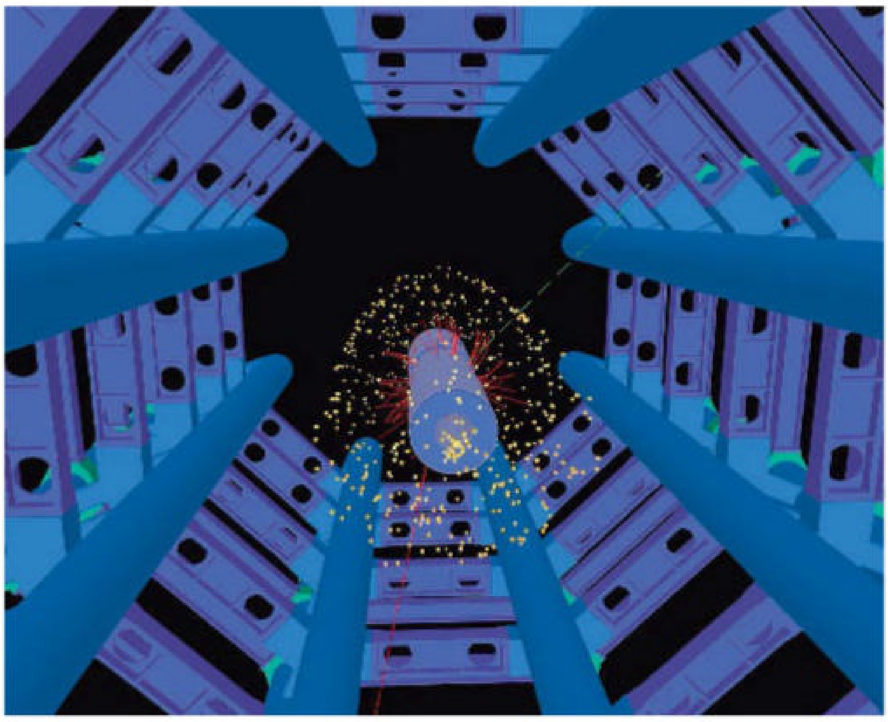


MARINE WOJCIESZAK

Particle physics

CERN measurement casts doubt on shock W boson result

Leah Crane



ATLAS COLLABORATION

Data from the ATLAS detector at the Large Hadron Collider

A TANTALISING discrepancy from the standard model of particle physics hasn't persisted in new results from CERN's Large Hadron Collider (LHC). While the previous result created a frenzy of hypotheses about new particles and adjustments to the standard model that could account for the discrepancy, there is growing evidence that it wasn't quite correct.

In 2022, researchers analysing archival data from the now-shuttered Tevatron collider in Illinois found that a particle called the W boson seemed to be ever-so-slightly more massive than predicted by the standard model. They found that it had a mass of 80.4335 gigaelectronvolts, while its widely accepted mass was 80.379 GeV.

Members of the ATLAS collaboration at the CERN particle physics laboratory near Geneva, Switzerland, were in the process of reanalysing their own data, which had always agreed with the standard model in the past, when the Tevatron results came out. The CERN researchers then used a more accurate method to reanalyse their results, improved by a stronger understanding of the particles involved and the data itself. The data was gathered by smashing two beams of protons together and analysing the trajectories of the various particles produced in the collision, and it required careful analysis over the course of years to come to a result.

80.360

CERN's value for the mass of the W boson in gigaelectronvolts

"The precision that you need to have is 0.01 per cent. That's the difficult part, to get it so precise," says Matthias Schott, a member of the ATLAS team at CERN. "We measure this with big detectors, which are several metres long, and we have to understand the particle track on the micrometre level."

The CERN researchers found a W boson mass of 80.360 GeV, in line with the predicted mass from the standard model and with all of the previous measurements, apart from the Tevatron one. "It's hard to say what's going on with the Tevatron result, but what you see is that every one of the other measurements sort of lines up in one column and they're an outlier," says Monica Dunford, another member of the ATLAS team.

Ashutosh Kotwal at Duke University in North Carolina, who led the Tevatron research, says that this work doesn't make him doubt his team's previous result. "We need new analyses and a fresh look at new data." Because the ATLAS work is a reanalysis of old data, it isn't surprising that it returned a similar result, he says.

But given that several other teams have performed experiments that agree with the ATLAS measurement, ATLAS researchers are confident in their result as well.

"We know the standard model is not complete, because there are lots of things that it can't explain, like dark matter, but this means that any new physics theory that we come up with in order to explain those things has to also adhere to this new precise measurement of the W mass," says Dunford.

The researchers are now analysing fresh data collected in 2018, and other teams at CERN are also working on their own measurements. For now, though, the excitement from the Tevatron measurement is dampened and it seems that the standard model continues to be the best description of particle physics as we know it.

Analysis Artificial intelligence

Are chatbots really able to think like people?

The lofty goal of artificial general intelligence is within reach, according to researchers at Microsoft, but others are sceptical, finds **Matthew Sparkes**

MICROSOFT researchers have claimed that OpenAI's GPT-4 is capable of such a wide variety of tasks, in some cases exceeding human ability, that this artificial intelligence model is showing "sparks" of artificial general intelligence (AGI). Is this long-awaited goal near or are these claims just hype?

While no standard definition of AGI exists, it is most commonly understood to refer to an AI that can understand and learn any intellectual task that humans are capable of. In a new paper, researchers from Microsoft Research say that they consider AGI to involve the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas and learn from experience – and that GPT-4 meets that criteria, despite only being designed to generate text.

"Given the breadth and depth of GPT-4's capabilities, we believe that it could reasonably be viewed as an early (yet still incomplete) version of an artificial general intelligence (AGI) system," they write.

Subjective and informal

GPT-4 launched to the public last month, but the Microsoft team devised a series of tests to evaluate a production version of the model before release. The group says the tests are based on ones from the field of psychology, which it admits are "somewhat subjective and informal" and may not stand up to scientific scrutiny.

Other researchers previously designed a suite of tests called BIG-bench, which is intended to offer a more rigorous assessment of an AI's abilities. Using a subset of these tests, the score for OpenAI's earlier AI model, GPT-3, was about half that achieved by people on average.



JAAP ARRIENS/NURPHOTO VIA GETTY IMAGES

The latest version of GPT launched to the public in March

Microsoft's new approach involved a variety of tasks. In one, the team asked GPT-4 to create a mathematical proof that there are infinitely many prime numbers, in rhyme. It correctly did so, in rhyming couplets.

In other tests, GPT-4 scored around 80 per cent on the multiple choice components of the US Medical Licensing Exam and 70 per cent on the Multistate Bar Exam, taken by lawyers in the US. When taking a software engineering test given to job candidates at Amazon, it scored 100 per cent, using less than 4 minutes of the allotted 2 hours (arXiv, doi.org/j35s).

It is hard to draw conclusions on the performance of GPT-4 from these tests alone. One unknown is whether the answers to these tests were already in its training data. A standard approach to creating and then testing an AI model is to use a large portion of available data to train it, but hold back a certain percentage in order to eventually test it on information it has never seen before. Critics have pointed out that OpenAI has provided minimal detail on what data was used to train GPT-4, making a truly independent analysis of its abilities difficult.

OpenAI itself has said that GPT-4 delivers "human-level performance" on a wide range of exams and tests, but also warns that the AI is still prone to "hallucination" – the phenomenon where an AI, in response to prompts, will produce convincing statements that are actually inaccurate or totally false. Indeed, Microsoft's early attempts to add GPT to commercial products have resulted in erroneous results containing false information.

The paper's authors weren't available for interview before publication, but a Microsoft spokesperson says that the company – which owns a significant stake in OpenAI – is "not focused on trying to achieve AGI".

80%

GPT-4's score on the US Medical Licensing Exam

4

Minutes taken by GPT-4 to get full marks on a software test

"Our development of AI is centered on amplifying, augmenting and assisting human productivity and capability. We are creating platforms and tools that, rather than acting as a substitute for human effort, can help humans with cognitive work," says the spokesperson.

Edward Johns at Imperial College London says that the inner workings of GPT-4 are very different to the human brain, but that the results in the paper show that each can achieve intelligence in their own way – even if AI is, at its core, learning to mimic what humans have done in the past.

"We could define AGI as being able to solve problems using language and it is doing as well as an average human," he says. "In terms of language-based reasoning, I can't think of many things that [GPT-4] would do worse than the average human on. You can have apparent intelligence without being intelligent in the same way as humans."

But some experts doubt that true AGI will ever arrive or that the admittedly impressive abilities revealed in the paper are signs of true intelligence. Mhairi Aitken at the Alan Turing Institute in London says we will see AI become increasingly capable and appear ever more intelligent, yet there will never be true understanding or real intentionality.

"There are lots of people who really, really believe that AGI is coming. I don't share that view," she says. "AI will always be programs that do what they're programmed to do. What they're programmed to do is to mimic human language or outputs, and they're getting increasingly good at it. So it becomes increasingly convincing." ■

Society

World population could soon peak

Working to reduce inequality could see the human population fall to 6 billion by 2100

Michael Le Page

THE global population will peak at 8.6 billion in 2050 and decline to 7 billion by 2100 if current trends continue, according to a projection by the Earth4All model from the Club of Rome non-profit organisation. And if the world invests more in reducing poverty and inequality, the number would top out at around 8.5 billion in 2040 and fall to 6 billion by the end of the century.

The figures are several billion lower in 2100 than other forecasts. "Even if the numbers are not going to be as scary as some older forecasts, this does not mean that we don't have a problem," says Beniamino Callegari at Kristiania University College in Oslo, Norway, one of the authors of the Earth4All report.

A big fall in the number of people on the planet will help alleviate environmental problems, but, by itself, won't stop us reaching "tipping points" where we risk destabilising Earth's life-support systems, says team member David Collste at Stockholm University in Sweden. "It's what people do, how they do it and how much they do it," he says.

A falling population will also decrease the proportion of working-age people, making it harder to finance healthcare and pensions. "The transition is not going to be easy," says Callegari.

While these latest projections are the lowest ones yet, all recent global demographic projections suggest that the world population will start to decline by the end of the century as a result of people having fewer children.

The United Nations says the world population passed 8 billion in 2022 and will grow to more than 10 billion before starting to decline around 2100.

The UN's forecasts extrapolate existing trends in population numbers, but models that account for the causal factors behind population trends have produced lower estimates.

For instance, Stein Emil Vollset at the University of Washington in Seattle and his colleagues have taken into account the level of education of women and access to contraception, and they project the population will peak below 10 billion around the 2070s and fall to about 9 billion by 2100.

The Earth4All model includes factors such as food production, income, taxes, energy and inequality. It also incorporates the expected worldwide impacts of global warming.

The Earth4All's business-as-usual projection is below the "most likely" projection from Vollset's team, but is "within the range of our scenarios with faster progress in female education", says Vollset.

A push to reduce inequality is needed to achieve the more-rapid population decline, says the Club of Rome. This would include investing trillions in green jobs, raising taxes on richer people, ensuring better education for more women, generating electricity from renewable sources and promoting healthier diets. ▮

The population in South Korea is falling despite efforts to prevent it



ALEXEY PANFEROV/ALAMY

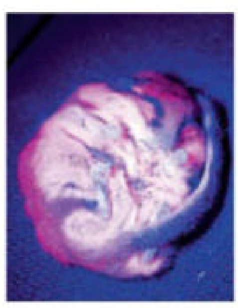
Zoology

Dormice glow brilliantly under ultraviolet light

GARDEN dormice may not seem particularly flamboyant. In fact, the small, brownish-white rodents spend much of their life trying not to be seen. But new research shows that, under the right light, these animals shine with bright shades of purple and greenish-blue.

Photoluminescence occurs when a substance absorbs photons of ultraviolet light and re-emits them at longer wavelengths, often as visible colours. This occurs in many marine animals, in some insects and millipedes and in the plumage of some birds. It encompasses two processes: fluorescence, when photons are re-emitted almost immediately, and phosphorescence, which can last for several minutes.

After seeing recent studies that also found photoluminescence in nocturnal mammals such as flying squirrels and springhares, Grete Nummert at Tallinn Zoo in Estonia wondered if garden dormice (*Eliomys quercinus*) display it too. She made a high-stakes bet with a colleague that this would be the case: "The losing one would bake a cake," says Nummert.



KARMEL RITSON

The fur of a garden dormouse appears purple under UV light

She and her team gathered a few of the garden dormice kept at Tallinn Zoo while they were sleeping and shone ultraviolet light on the animals. Most of the mice's fur glowed a bright purple colour. The feet and the nose, on the other hand, appeared bluish green (*Zoology*, doi.org/j3x3).

Nummert, who says the cake she won was "delicious", isn't sure yet why the dormice have this trait or whether they can perceive it themselves. Some parrots use photoluminescence to signal to potential mates. Springhares have a patchy photoluminescence that may help camouflage them among plants that reflect light in a similar way, depending on what kind of creatures are looking.

It is also possible that the photoluminescence exhibited by dormice and other rodents is just a by-product of something they eat or some other natural process. ▮

Joshua Rapp Learn

Analysis Energy

Europe averted a crisis over winter, but what happens next time round?

Madeleine Cuff

SIX months ago, an energy disaster loomed in Europe. Spiking gas prices, driven in large part by Russia's invasion of Ukraine, had sent costs soaring and sparked a worldwide scramble for energy supplies. Headlines warned of a winter of rolling blackouts and fuel shortages, a nightmare scenario that would crash Europe's economy and endanger lives.

Compounding the problem was a once-in-500-year drought, which dramatically cut power output from hydroelectricity and Europe's already beleaguered network of nuclear power plants. This created an extra gap in generation equal to 7 per cent of Europe's total electricity demand in 2022, says energy think tank Ember.

Yet as the continent enters spring, it appears those doomsday predictions never came to pass. While millions of people experienced a season of cold homes, and factories reduced their output in response to high prices, the feared full meltdown never came to pass. So just how did Europe's energy system manage to cope? And with Russia's war in Ukraine showing no signs of ending, can the continent repeat the same trick next winter?

"We've been lucky," says Lion Hirth at the Hertie School in Germany. "It was a relatively mild winter." A warm autumn meant biting cold arrived later in Europe than usual, and even those frigid days were short-lived. Across Europe over the new year, temperatures hit record highs, nearing 20°C in Warsaw, Poland, and 25°C in Bilbao, Spain. The warm start to 2023 may have ruined the continent's ski season, but it cut demand for central heating and gave energy suppliers a chance to top up gas storage tanks in case of a late cold snap.

The warm weather reduced consumption, but high prices pushed energy users to cut back even further. Electricity use in the European Union fell by almost 8 per cent in the final quarter of 2022, says Ember, a drop similar in scale to that seen in the first wave of coronavirus lockdowns.

In Germany, households and small businesses cut their gas use by more than 20 per cent, says Hirth, even after the mild winter is accounted for. Part of this "demand destruction" was driven by high prices, but there was also a sense of the public pulling together to weather the storm and support Ukraine, he says.

41

EU's new solar power generation capacity, in gigawatts, in 2022

"My friends and family, people I know, they are all saving a lot of gas," says Hirth. "It's a big effort. It's just very common that people put on two sweatshirts if they are cold."

The drop in demand also meant a feared resurgence of coal failed to materialise. Leaders in the UK and EU ordered emergency coal plants to be on standby during winter, and millions of tonnes of extra coal were imported, but, in the end, coal-fired electricity generation increased by just 1 per cent in the EU during 2022. In the UK, it actually fell by 15 per cent.

Instead of coal, renewables swooped in to save the day, according to Ember's Harriet Fox. "Wind and solar performed massively well, and without them, we'd have been even more reliant on a return to coal," she says. In particular, solar grew at a staggering rate. The EU added a record 41 gigawatts of new capacity during 2022, 47 per cent more than in 2021. That helped to bolster green electricity generation. In the Netherlands, for example, solar provided 14 per cent of electricity during 2022, overtaking coal for the first time.

But although energy experts are relieved, there are no guarantees next winter will be plain sailing. For starters, now that energy prices are subsiding, demand is likely to rebound. Industry will start using more power as production lines return to full strength and households may become more liberal with their use of central heating.



A liquid natural gas facility in Melkoeya, Norway

OLE BERG-RUSTEN/NTB/AFP VIA GETTY IMAGES

For permanent demand reduction, governments must focus on encouraging people to install energy efficiency measures like extra insulation, heat pumps and double glazing, says Fox.

Continuing the rollout of renewables is also essential to ensure supply keeps up with growing demand, she says. Signs look promising: in December, the EU approved emergency legislation to deploy solar and wind power quickly over the coming months.

But the weather could yet cause major disruption. Across parts of Europe, a dry winter and sparse snowfall have sparked fears that this summer could bring another intense drought. This would have severe consequences for the energy system, once again depleting hydropower production and curtailing nuclear generation. A hot summer could also push up demand for gas-fired electricity to power air conditioning units, right at the moment Europe will need to be banking as much gas as possible for winter.

Yet Hirth remains optimistic that the worst is over. "There are extraordinary things, like a major terrorist attack, a major cyberattack on the gas infrastructure, or let's say the coldest winter in 20 years – those things can happen, but it's unlikely," he says. "And save these black swan events, I don't see how Europe could get in a situation that is in any way comparable to last year, where people were – for good reason – concerned about physical shortages." ▮

Analysis **Artificial intelligence**

The problem with an unusually fashionable pope

We are in a new age of misinformation as a result of the growth of image-generating tools, says **Chris Stokel-Walker**

AN IMAGE of Pope Francis, the leader of the Catholic church, wearing a large, white puffer jacket went viral last week. The 86-year-old pontiff looks stylish, with many people commenting on his fashionable clothes. There is just one problem: the image isn't real.

The picture (right) is part of a set generated by the artificial intelligence Midjourney, which produces images based on text prompts, and were posted on Reddit on 24 March by an artist who goes by the name of u/trippy_art_special. The user's account has since been suspended, but this image in particular has spread across Twitter, where it has fooled many.

Should we be worried? Web culture expert Ryan Broderick has called the pope image "the first real mass-level AI misinformation case". But the issue has actually been brewing for a few weeks, following an update to Midjourney that significantly improved the standard and realism of its output, making it easier to trick people. For example, early in March, Midjourney was used to create images of former US president Donald Trump seemingly being handcuffed and arrested, and these similarly went viral. Those images were generated from prompts provided by Eliot Higgins, the founder of Bellingcat, an investigative journalism group.



MIDJOURNEY/REDDIT

This image of Pope Francis was generated by artificial intelligence

"I think this is an example of a wider problem of technologies being pushed into our societies without any oversight, regulation or standards," says Elinor Carmi at City, University of London.

Fears of AI fakery aren't new. For several years, we have faced the threat of deepfaked images of people's faces, produced by earlier generations of AI trained on smaller volumes of information, but they have frequently had telltale signs of fakery, such as non-blinking eyes or blurred ears. Midjourney still struggles with hands, often adding additional fingers, but when confronted by an image where hands aren't the focus, such as the AI pope, people can be fooled.

There is also an issue of scale, says Agnes Venema at the University of Malta. The r/midjourney subreddit where the pope images were posted has examples of other, equally convincing AI-generated images produced by its 143,000 members. They include a series of photographs documenting a fictional earthquake that hit the US and Canada in 2001 that has inspired its own lore. The top-voted comment on the post reads: "People in 2025 are going to have a real difficult time with misinformation. People in 2100 won't know which parts of history were real…"

"I think the fact that so many people can now access it – in a way, it is more democratic – means that, in a way, the floodgates have opened," says Venema. "The more realistic it gets and the more people gain access, the more careful we should be and the more risk there is of someone acting on this type of deception."

> **"This is an example of technologies being pushed into our societies without any oversight"**

Ultimately, the rapid rise of AI means some disruption is inevitable. Carmi says we are being expected to hop on board the AI revolution without fully grasping its impact – meaning we need better media literacy of how easy it is to create and spread fake images.

"Most of our society has been left behind, not understanding how these technologies work, for what purposes and what are the consequences of that," she says. ■

Space

JWST telescope finds TRAPPIST-1b may have no atmosphere

THE James Webb Space Telescope has looked at a promising star system with exoplanets thought to have an atmosphere, but didn't find any sign of this. Some models had predicted that such worlds would have thick atmospheres, but their absence could lower the estimate of potentially habitable planets in the cosmos.

The TRAPPIST-1 system consists of a red dwarf star with at least seven planets orbiting it, four of which are in the habitable zone – the area around a star where temperatures allow for liquid water. Thomas Greene at NASA's Ames Research Center in California and his team used JWST to study TRAPPIST-1b, the planet closest to the star.

They looked at this world before and after it passed behind the star, which is the optimal time to spot how heat from the star is affecting the planet. "People were predicting that these planets would have pretty thick atmospheres that would circulate the heat around the planet, so they wouldn't be very bright," says Greene. "So we took five observations because we thought we would have to stack them up to see anything, but when the data came back it was staring us right in the face."



NASA

Artist's impression of TRAPPIST-1b, the closest planet to its star

TRAPPIST-1b was far brighter than the researchers expected, indicating that the sunlight was hitting one side of the planet and not being absorbed by a thick atmosphere. The temperature of that side of the planet, called the day side, was about 230°C (446°F), about 100°C hotter than we would expect if there was an atmosphere distributing the heat around it (*Nature*, doi.org/grz99p).

The most likely explanation is this planet's atmosphere was lost soon after its formation, when the star was brightest, or that a stellar flare stripped it away. "There's a lot of energy getting dumped onto the planets, and that can do bad things to atmospheres," says Greene. ■

Leah Crane

Health

Why is cancer rising in younger people?

The number of people under 50 with cancer is increasing in many countries and for many different tumour types. The hunt is on to find out why, reports **Clare Wilson**

WHEN it comes to cancer research, we regularly hear good news about the number of people benefiting from advances in treatment. But there is one bad news story about the condition that gets little attention. For three decades, there has been a gradual rise in the number of people under 50 being diagnosed with cancer – and we don't entirely know why.

The rise is steepest in bowel cancer, but an increase in incidences is happening with tumours of nearly all the major organs of the body. It is so alarming that it was made a top priority for research in a joint UK-US cancer funding review last month. So, what might the causes be?

The incidence of cancer rises with age, mainly because the cells of older people have had longer to acquire the genetic mutations that cause tumours.

Around 9 in 10 cancerous tumours occur in people over 50, so the increasing incidence in people younger than this isn't making a big impact on the total number of cases. "It's important to remember that the vast majority of cancer cases are diagnosed in people over 50," says Alice Davies at Cancer Research UK (CRUK).

Yet the trend is worrying, partly because it shows no signs of stopping. Young people should be in the prime of their lives and are often caring for children, says Marios Giannakis at the Dana-Farber Cancer Institute in Boston, Massachusetts.

"It's an absolutely devastating day when you see young patients diagnosed with cancer," he says. Giannakis called for an investigation into the reasons behind the rise in bowel cancer specifically in an opinion article in the journal *Science* last month.



PAUL MORIGI/GETTY IMAGES

A rally for colorectal cancer awareness in Washington DC

A Western diet made up of processed meat may be causing a rise in cancer



ZELJKODAN/SHUTTERSTOCK

For most types of tumour, their increase in people under 50 has been relatively modest so far. For instance, the incidence of all cancers combined among 25 to 49-year-olds in the UK rose by 22 per cent between 1993 and 2018, from 133 cases per 100,000 people to 162 per 100,000.

But the fact that the same trend is being seen in many different cancer types in high, middle and low-income countries suggests that it should be seen as an emerging global epidemic, said Shuji Ogino at Harvard Medical School in a review of World Health Organization figures last year. "I believe the trend won't stop anytime soon and it may accelerate," he says.

The figures for bowel cancer are the most alarming, with about a 50 per cent rise in people aged 25 to 49 since the 1990s in the UK, for example. There is a similar pattern in the US, Canada, Australia, South Korea and several European countries, including Sweden, Finland and the Netherlands.

At first glance, the phenomenon might be ascribed to the relatively recent practice of cancer screenings finding tumours that wouldn't otherwise have been noticed, but this could only be causing some of the increase. In the majority of countries, screening is only offered to people from about the age of 50, depending on the tumour type. Most of the cancers that are rising also can't be screened for.

"I believe the trend of cancer diagnoses in young people won't stop anytime soon and it may accelerate"

In addition, the rise in bowel cancer seems steepest among those in the youngest age bands, who are rarely offered screening. Across 20 European countries, the rise has been by about 2 per cent per year in people in their 40s,

5 per cent in those in their 30s and 8 per cent in those in their 20s.

This suggests that whatever the cause is, it is intensifying, says Manon Spaander at Erasmus University Medical Center in Rotterdam, the Netherlands, who helped to demonstrate this decade-based pattern in a 2019 analysis.

Changing diet

Another cause for concern is that some of the cancers that are rising in people under 50 seem to be more aggressive than those in older people. This is the case for tumours of the bowel, breast and prostate.

That may be partly because younger people take longer to be diagnosed, perhaps because cancer is less likely to be suspected in this age group. Tumours in people under 50 are also more likely to have certain innate features, such as genetic mutations that are harder to treat.

In most cases, cancers are thought to take several decades to develop, as cells gradually acquire more and more mutations that let them escape our bodies' natural brakes on cell replication. If people are developing tumours in their 20s, 30s and 40s, it is probably because of things they have been exposed to in their childhood or perhaps even while in the uterus, says Ogino.

The most obvious suspicion is that this increase in cases is something to with changes to our diet, especially because the largest rise is in bowel tumours, with our digestive system coming into direct contact with the food we eat. In fact, of the 14 cancer types where a rise has been recorded in under-50s, eight involve some part of the digestive system, such as the oesophagus (or food pipe), stomach and gall bladder.

It was already thought that some aspects of the Western diet, such as eating a lot of red or processed meat, could raise the risk of bowel cancer. Supporting this, the biggest rise in bowel cancers in those aged 18 to 49 – classed as early onset – has been in tumours that arise in the lower portion of the bowel and rectum, next to the anus, and these cancer types are those most often linked with eating processed red meat, says Giannakis.

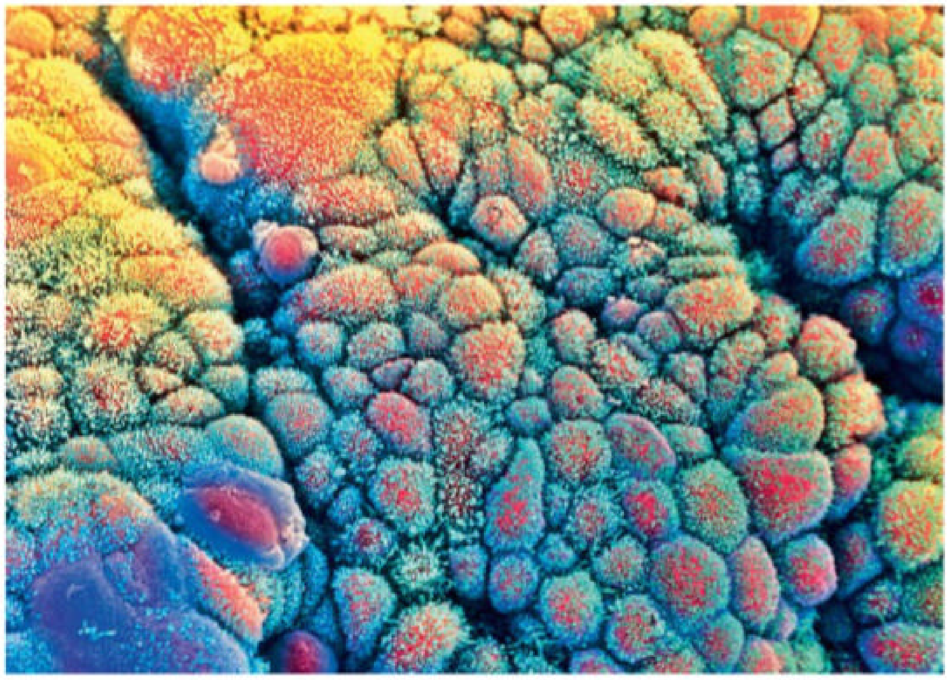
But the claims for the cancer-causing properties of red meat are contested and there are many other features of Western-style diets that could be responsible, including sugar, fat, ultra-processed food and refined carbohydrates such as white bread, as well as a lack of fibre. Another suspect is what is arguably one of the Western diet's net effects: a rise in obesity levels. Some studies suggest that people who are overweight or obese have a higher rate of certain cancers.

The cause may not even be directly related to what food people eat, but some other aspect of modern life, including the shift to a more sedentary lifestyle or our increasing exposure to certain environmental pollutants.

9 in 10
Proportion of cancerous tumours that occur in those over 50

22%
The rise in cancers in 25 to 49-year-olds in the UK between 1993 and 2018

14
The number of cancer types with a recorded rise in the under-50s



A scanning electron micrograph of cancer cells in the intestine

STEVE GSCHMEISSNER/SCIENCE PHOTO LIBRARY

Another possible cause is the use of antibiotics because of their potential impact on our gut bacteria. The timing fits, as antibiotics came into use in the 1950s and people who were then children would have reached their 40s in the 1990s, when the rise in early-onset cancer began, says Spaander.

Research required

With so many possible causes, finding out the answer has to be a priority for cancer research, two major funders – CRUK and the US National Cancer Institute – have agreed. Last month, the organisations made this goal one of their nine joint research priorities, which they call Cancer Grand Challenges.

We need huge long-term studies that follow people from a young age and record their eventual rates of cancer, tracking their lifestyle and environments – sometimes called their exposome – while taking regular samples of blood and, ideally, faeces, says Sherene Loi at the University of Melbourne, Australia, who helped to set up the Cancer Grand Challenges.

Fortunately, this Herculean research doesn't need to be started from scratch as there are many such studies that have already been set up to investigate the relationship between our health and lifestyle. Cancer researchers could piggyback their efforts onto these to extract the relevant data, she says.

For now, it would be premature to advise the public to avoid any of the mooted risk factors before we have answers, says Loi. "We don't yet understand any of the reasons," she says. "At the moment, we're just poking around in the dark." ■

Solar system

Fissures on icy ocean moons may be too rare to provide conditions for life

Leah Crane

THE seafloors of Europa and Enceladus may not be prone to fracturing. Such fissures are thought to be important for the prospect of life beneath these moons' icy shells, so if there isn't enough stress to cause them, there may also be a shortage of energy and chemicals that potential living organisms would need.

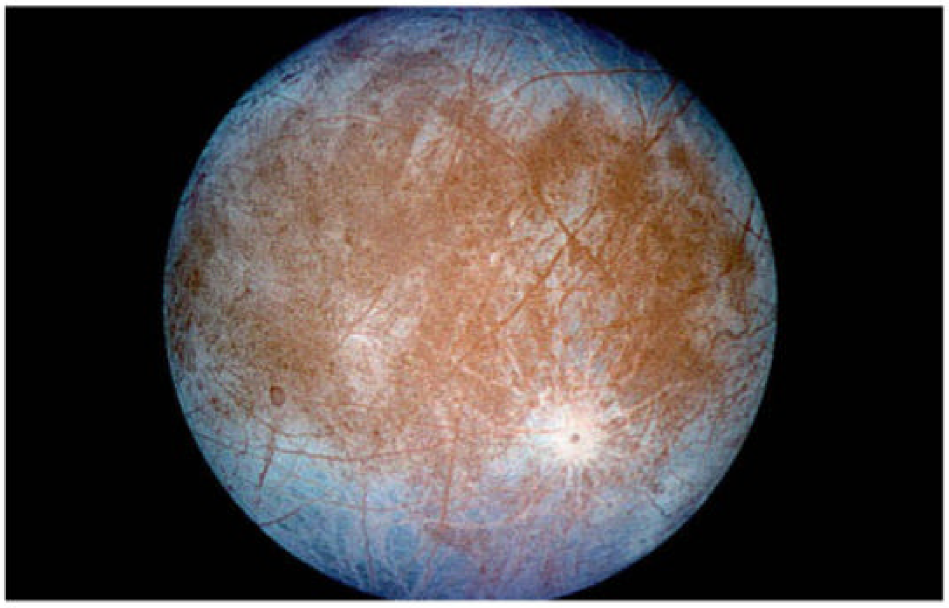
We can't observe the cores of these frigid worlds directly, so we know very little about them. If they fracture often, the fresh rocks revealed could react with the waters overlying them to provide energy and nutrients for potential life in those oceans.

Henry Dawson at Washington University in St. Louis, Missouri, and his colleagues modelled some of the stresses on the icy moons' rocky cores to see if those stresses could crack the rock.

The researchers focused on three main sources of stress to the rock of the seafloors. The first was tidal stress, which occurs because the gravity of the planet – Jupiter for Europa and Saturn for Enceladus – pulls on one side of the moon more intensely than the other, stretching it slightly.

We know from surface features on Enceladus and Europa that this effect is strong enough to crack ice, but the researchers found that it was far from powerful enough to crack the moons' rocky cores. "Even with the weakest rock we can really find, we are still a factor of three lower than we would require [for tidal stress to cause fracturing]," Dawson told the Lunar and Planetary Science Conference (LPSC) in Houston, Texas, on 17 March.

Europa is a large, icy moon that orbits Jupiter


NASA

The second source of stress the researchers considered was contraction of the moons as they cool. They calculated that the solid interior of Europa would have to contract by more than 1 kilometre in diameter in order to cause fissures, which is so significant that it is unlikely to have occurred at all. Enceladus is much smaller than Europa, so it might have shrunk enough to cause faults, but only if it cooled extremely quickly since its formation.

The final source of stress was pressure on the rock from below due to rising magma. The researchers found that this was a plausible way to cause faulting, but we know so little about how magma forms and moves in these sorts of environments that it is impossible to tell for sure.

The work is preliminary, but it isn't looking good for seafloor fissures. "If there aren't enough stresses to produce regular faulting of the rock, that would lead to a less nutrient-rich ocean," said Dawson. "It would be leaning against the possibility of life."

As members of the audience at LPSC pointed out, this is still a bit pessimistic – there may be other ways to weaken the seafloor and create fracturing that Dawson and his colleagues haven't yet investigated, such as expansion of the cores due to reactions between the rocks and the water. Life in the oceans of Europa and Enceladus may not seem as likely as it did before, but it isn't ruled out yet. ■

Chemistry

Wrinkly graphene could transform hydrogen fuel cells

TINY ripples on graphene's surface let it split hydrogen 100 times more efficiently than any known chemical catalysts. The discovery could lead to improved hydrogen fuel cells.

A one-atom-thick layer of carbon, graphene is essentially a slice of graphite. The latter is an extremely unreactive substance because of its strong carbon bonds. However, Andre Geim at the University of Manchester, UK, and his colleagues have found that graphene, despite also having strong bonds, can be very chemically reactive. This is because it tends not to be totally flat, instead having small undulations in it called nanoripples. These allow it to split hydrogen as effectively as the best catalysts we have today.

To show this, the team produced graphene with as few defects as possible to rule out the effects coming from some other feature, then stretched a sheet of it across the top of a microscopic container filled with hydrogen molecules.

As the graphene split the hydrogen into individual atoms, they built up inside the container, increasing the pressure, making the graphene bulge. The team measured the size of the bulge to calculate graphene's catalytic power.

Its ability per gram to split hydrogen was at least 100 times that of the most widely used catalysts, such as copper or magnesium oxide. However, if you compare the efficiencies of catalysts to their surface area, copper comes out slightly better than graphene.

"Catalysts based on pure carbon can potentially change many industrial processes"

Geim's team also compared an almost perfectly flat sheet of graphene with one with nanoripples and only the rippled one split hydrogen (*PNAS*, doi.org/grxcvq).

"Most industrial chemical reactions are driven by catalysis, so if we produce catalysts based on pure carbon… then it potentially can change many industrial processes," says Andrei Khlobystov at the University of Nottingham, UK, such as for hydrogen splitting, a process central to hydrogen fuel cells that can produce clean electricity. ■

Alex Wilkins

Philosophical, curious & puzzling…

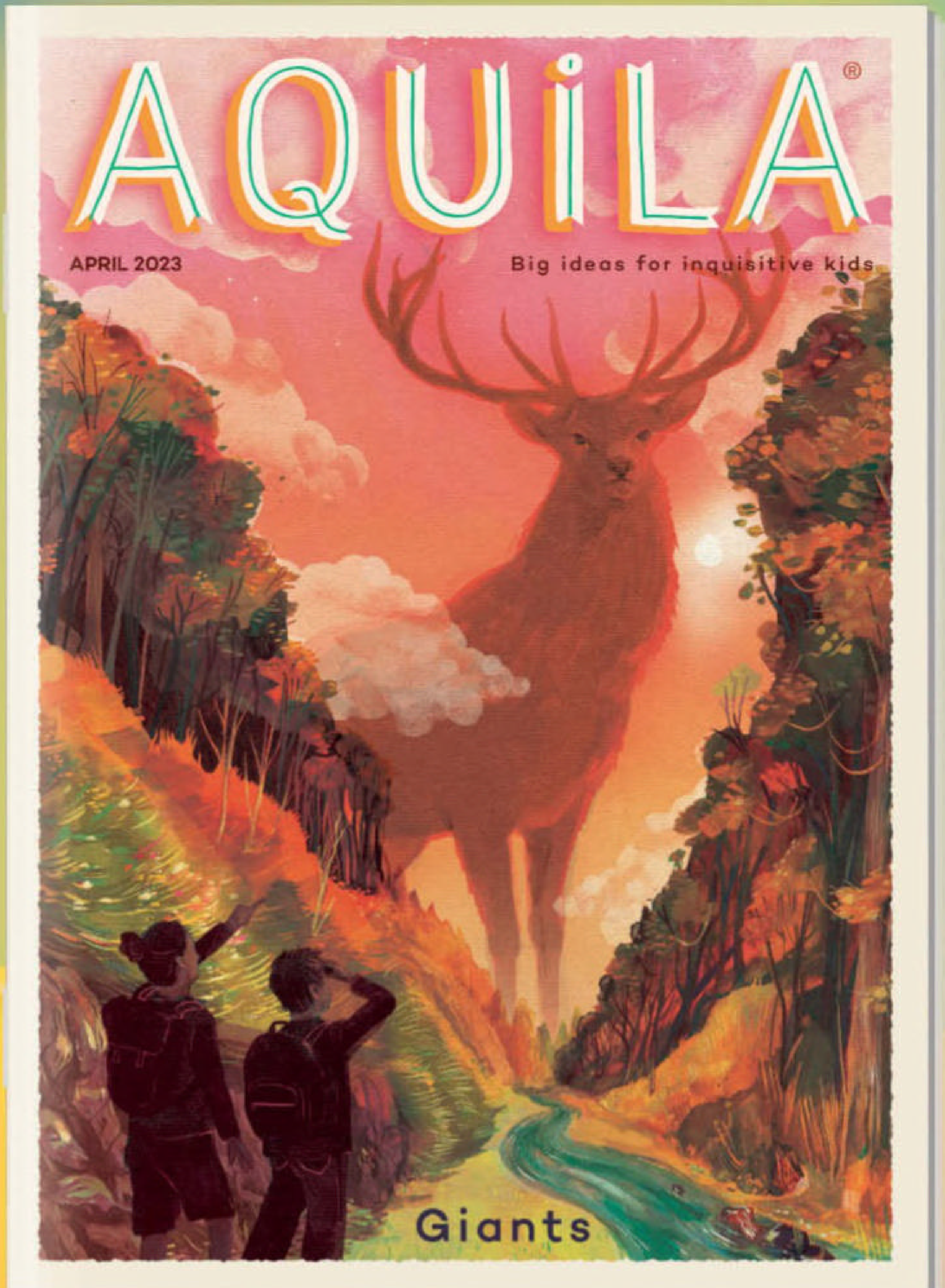
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FRANK MARTELA

Space

Asteroid samples contain a building block of RNA

Leah Crane

SAMPLES from the asteroid Ryugu contain uracil, one of the four building blocks of RNA. This lends credence to the idea that the ingredients for life were brought to Earth by space rocks.

Japan's Hayabusa 2 spacecraft returned 5.4 grams of asteroid dust from Ryugu at the end of 2020, and various labs obtained tiny portions to examine. Yasuhiro Oba at Hokkaido University in Japan and his colleagues steeped their samples first in hot water for 20 hours, then in hydrochloric acid. Lastly, they searched the resulting tea-like extracts for nucleobases, components of DNA and RNA.

Even though the researchers started with samples weighing less than 20 milligrams, and only 20 to 30 per cent of the extracts were used for this study, they managed to find uracil, as well as complex organic molecules. This isn't the first time such compounds have been found in extraterrestrial rocks, but the other findings were from meteorites that had spent time unprotected on Earth's surface, whereas the Ryugu samples were pristine, straight from the asteroid's surface (*Nature Communications*, doi.org/j3t3).

"In previous studies, we could not completely rule out a possibility that the detected nucleobases were terrestrial contaminants," says Oba. "This time, under careful contamination control, the Ryugu samples are free from terrestrial contamination, so this is strong evidence that uracil is really present in extraterrestrial materials."

If uracil is present, other compounds key to life may exist on Ryugu as well, but we haven't been able to see them because of the small size of the samples. Luckily, NASA's OSIRIS-REx spacecraft is on the way back from an asteroid called Bennu with more than 400 grams of asteroid dust, and should arrive in September.

Global health

Safe drinking water remains out of reach for billions

Jason Arunn Murugesu



GILES CLARKE FOR THE NEW YORK TIMES VIA GETTY IMAGES

Women collecting water amid a severe drought in Somalia

AROUND 2 billion people don't have access to safe drinking water, a major United Nations report has found.

Several factors are to blame, says Richard Connor at the UN, the report's lead author. Rising urban populations, expanding agriculture, a lack of waste water-treatment infrastructure and climate change all play a role, he says.

The *UN World Water Development Report* was published to coincide with the UN's first major conference on water since 1977, which took place last week in New York. It ended with hundreds of pledges from governments and other organisations, but no internationally binding agreement.

The report is intended as an update on progress towards ensuring that everyone in the world has access to safe drinking water by 2030 – one of the UN's sustainable development goals adopted in 2015.

This goal is severely off track, says Connor. "Achieving universal coverage by 2030 will require a quadrupling of the current rates of progress in the provision of water and supply services."

The report found that the global demand for water has risen by 1 per cent each year for the past 40 years and will continue to increase at a similar rate for the next 30 years.

46%

Proportion of the world's population without sanitation

"This growth in demand is concentrated in emerging economies and lower-income countries," says Connor. In particular, urban water demand is projected to increase by 80 per cent by 2050.

The provision of adequate waste water-treatment infrastructure isn't keeping up with this increase in demand, the report found. It says 80 per cent of the world's waste water flows back into the environment without being treated or reused. Consequently, at least 2 billion people use a source of drinking water that is contaminated with faeces, which puts them at risk of diseases such as cholera.

Climate change is likely to make it even harder to access clean water around the world, says Connor. Seasonal water scarcity will become more common in places that don't currently experience such issues and more acute in regions where it is already a major problem, he says.

The global urban population facing water shortages is projected to increase from 933 million people in 2016 to 2.4 billion people in 2050, with India projected to be the most affected country.

The report also found that 3.6 billion people, or 46 per cent of the world's population, lack access to a toilet or latrine that disposes of human waste safely.

Connor says the lack of access to water and sanitation around the world comes down to insufficient political will and priority-setting. He hopes the UN will adopt more pragmatic goals: "Instead of going for the moon and saying that every single person on Earth should have access to all of these services, I would like to see something more realistic and make it a binding agreement that states are responsible to meet."

"What is clear is that a monumental shift in ambition and approach is needed," says Claire Seaward at WaterAid. "There is no magic bullet to this. What it really requires is that we all come together to strengthen the whole of the water and sanitation system."

Mathematics

Shape discovered that can tile a wall and never make a pattern that repeats

Matthew Sparkes

MATHEMATICIANS have found a single shape that can be used to cover a surface completely without ever creating a repeating pattern. The long-sought shape is surprisingly simple, but has taken decades to uncover – and could find uses in everything from material science to decorating.

Simple shapes such as squares and equilateral triangles can tile, or snugly cover a surface without gaps, in a repeating pattern that will be familiar to anyone who has stared at a bathroom wall. Mathematicians are interested in a more complex version of tiling, known as aperiodic tiling, which involves using shapes that don't ever form a repeating pattern.

The most famous aperiodic tiles were created by mathematician Roger Penrose, who, in the 1970s, discovered that two shapes could be combined to create an infinite, never-repeating tiling. Now, Chaim Goodman-Strauss at the University of Arkansas and his colleagues have found a single tile shape – which they have called "the hat" – that does the same job.

Goodman-Strauss says that both finding and proving the tile to be aperiodic involved the use of computers and human ingenuity. The researchers used computers to eliminate lots of options, then applied their experience to finding a shape and developing a proof (arxiv, doi.org/j3tw).

"You're literally looking for like a one in a million thing. You filter out the 999,999 of the boring ones, then you've got something that's weird, and then that's worth further exploration," says Goodman-Strauss. "Then, by hand, you start examining them and try to understand them, and start to pull out the structure. That's where a computer would be worthless, as a human had to be involved in constructing a proof that a human could understand."

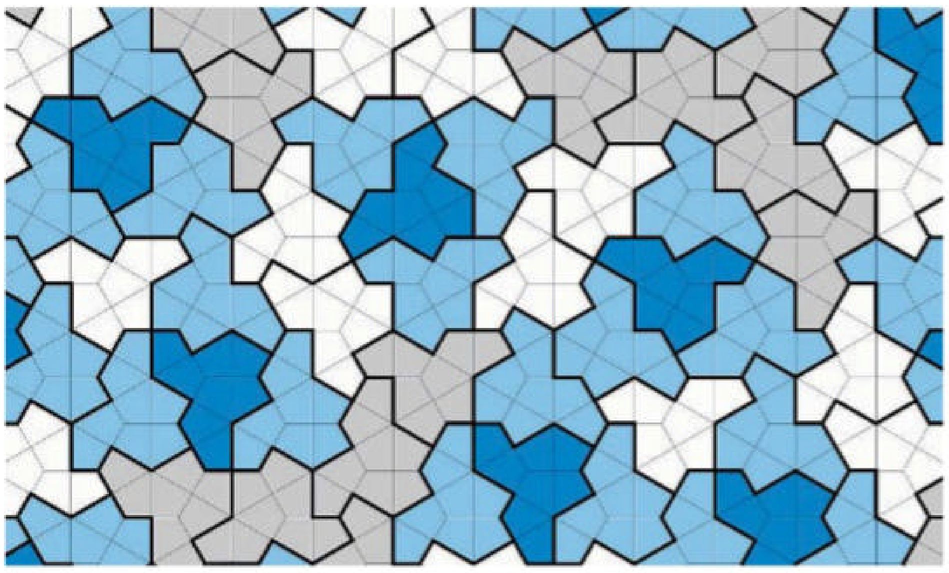
Until now, it wasn't even clear that a single shape, known as an einstein (from the German *ein stein* or "one stone"), could even exist. Sarah Hart at Birkbeck, University of London, who wasn't involved with the study, says she thought it would be impossible. "There are infinitely many possible candidate tiles, and even the existence of a solution feels quite counter-intuitive."

Despite evading us for decades, the newly discovered einstein isn't a convoluted or complex shape – it features just 13 sides. Much of the difficulty in finding an einstein is proving that it really can tile aperiodically, without throwing up unusual counterexamples. The team discovered two proofs, with one based on computer code that has been publicly released.

Colin Adams at Williams College in Massachusetts says he was shocked at the simplicity of the solution, and that this was a problem that "does not easily yield to brute force" computation. He is also keen to put it to practical use.

"You're going to see people putting these in a bathroom because it's just cool. I would put it in my bathroom if I were tiling it right now," he says. ■

The shape has 13 sides and has been dubbed "the hat"



CRAIG S. KAPLAN

For more maths, see page 36

Health

Botox injections alter brain activity linked to emotions

AFTER having Botox injections in the forehead, people's brains respond in a different way when they see images of faces showing emotion. This may mean they find it harder to interpret others' emotions.

Mitchell Brin – who works at AbbVie, which makes Botox, and at the University of California, Irvine – and his colleagues scanned the brains of 10 women aged between 33 and 40 before they had injections of botulinum toxin, commonly known as Botox, to smooth wrinkles in their foreheads and again two to three weeks later. The study didn't include any men. The injections paralysed muscles so participants could no longer frown or smile with their whole faces.

During functional magnetic resonance imaging of their brains, the participants looked at photos of angry and happy faces interspersed with neutral images. After receiving Botox, volunteers had altered activity in a brain area called the amygdala when looking at angry and happy faces, and in the fusiform gyrus when looking at happy ones (*Scientific Reports*, doi.org/j3h4).

Normally, when we see expressions, we unconsciously mimic them to help us recognise them, says Fernando Marmolejo-Ramos at the University of South Australia. As our facial muscles copy the other person's frown or smile, they send signals to brain areas like the amygdala and fusiform gyrus that interpret the emotions, he says.

"You might not be able to experience someone else's emotions as intensely or vividly as you would like"

Botox's restriction of muscle movement may disrupt this communication, so "you might not be able to experience someone else's emotions as intensely or vividly as you would like to", says Marmolejo-Ramos.

AbbVie didn't respond to a request for comment.

The finding fits with other studies showing that Botox injections can make it harder to recognise and process emotions. ■

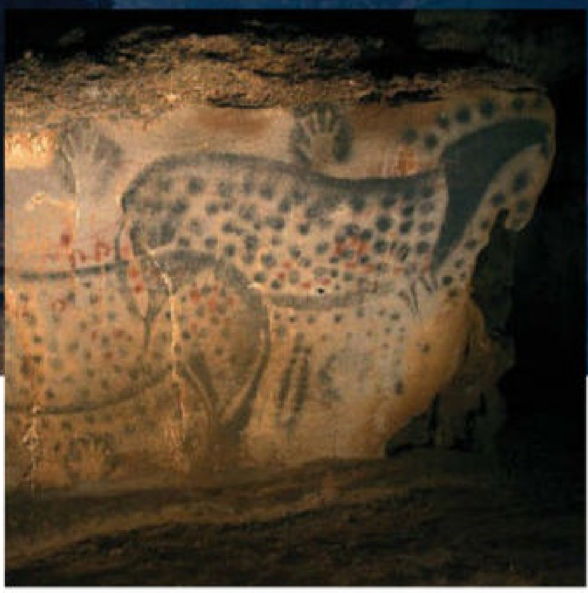
Alice Klein

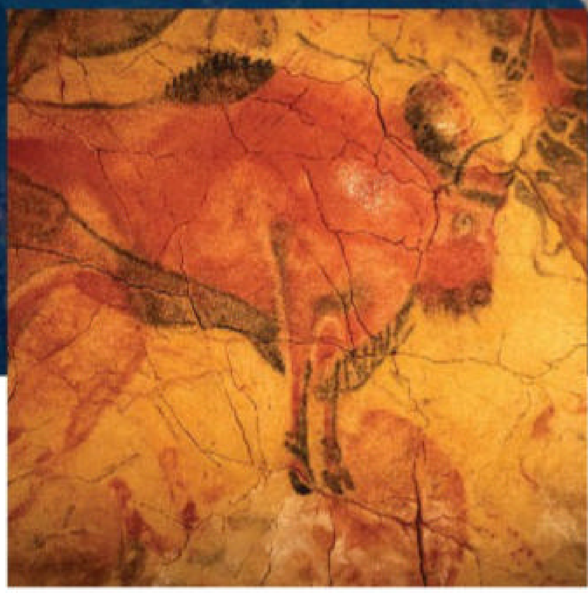
See page 38 for "The truth about wrinkles"

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In this tour, Rebecca shows how advances in archaeological methods, have transformed our understanding of these ancient ancestors. Far from confined and unvarying, Neanderthal minds were focused on quality and efficiency, yet also flexible and creative. As stone artisans, carpenters and inventors of the first synthetic material, Neanderthals pioneered new technologies, and they lived not just through ice ages but in warm woodland worlds too.

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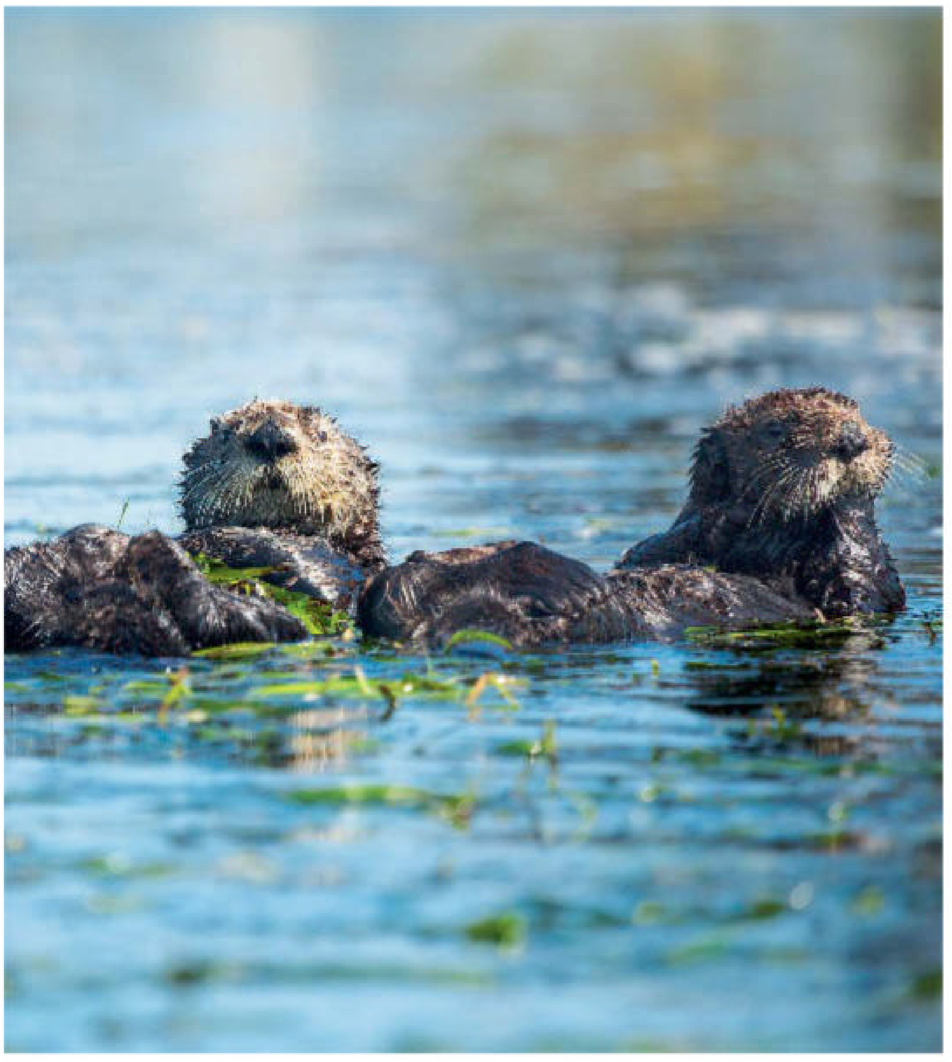
Technology

Cheesecake made by a 3D printer

A 3D-PRINTING lab has automated the assembly and cooking of a seven-ingredient cheesecake.

"When you bite into it, you kind of feel the flavours hit you in different waves," says Jonathan Blutinger at Columbia University in New York. "And I think that's a function of the layering inside of the actual structure."

Blutinger and his colleagues used seven ingredients, including graham crackers, peanut butter and strawberry jam. Any ingredient not already in a paste form went into a food processor. A 3D printer could then build up the cake by depositing the seven paste-like ingredients in layers. A laser beam just a few millimetres wide then lightly browned the outer graham cracker portions (*npj Science of Food*, doi.org/j3xd). **Jeremy Hsu**



CHASE DEKKER WILD-LIFE IMAGES/GETTY IMAGES

Health

Key to sleep may be a high-protein diet

A HIGH-PROTEIN diet may promote deeper sleep, according to a study that found mice and flies that eat more protein are less likely to wake up from movement-related disturbances.

When you go to sleep, you stop consciously perceiving the world, including things that may disrupt sleep, says Dragana Rogulja at Harvard University.

She and her colleagues fed flies either a high-protein diet or a regular diet for one day. Half as many flies on the high-protein diet woke in response to vibrations from a loudspeaker as flies on a regular diet. A similar experiment in mice produced comparable results (*Cell*, doi.org/j3xg).

"The general idea makes sense. We sleep when our other needs are taken care of," says Rafael Pelayo at Stanford University in California. **Grace Wade**

Biology

Parasite from cat faeces killed four sea otters

FOUR sea otters in California have died from infection with a rare strain of the parasite *Toxoplasma gondii*, which is primarily found in cats and transmitted through their faeces. This is the first recorded instance of this form of toxoplasmosis in a marine animal, and could mean an unusually virulent strain of the parasite is circulating on land.

"Otters are really good at showing what comes from land to sea," says Melissa Miller at the California Department of Fish and Wildlife. Their diet of bivalves, which filter water, means runoff contaminated with *T. gondii* eggs can end up reaching otters. The parasite commonly causes chronic infections in otters, but it is unusual for it to rapidly kill adults, she says.

Miller and her team performed necropsies on four southern sea otters (*Enhydra lutris nereis*) found stranded between 2020 and 2022, all during the February and March rainy seasons. Three adult female otters were stranded near Big Sur in San Luis Obispo county in California; one younger male was found about 170 kilometres further north.

The otters had more parasites in more tissue types than usually seen in toxoplasmosis, and they had inflamed fat associated with the presence of parasites (*Frontiers in Marine Science*, doi.org/j3xc). "As soon as I started looking at them under the microscope, I was like, 'whoa'," says Miller.

The researchers found that key sequences of the parasite's DNA were identical to a strain that had previously been reported only in a pair of mountain lions in British Columbia, Canada, in 1995 and a wild pig in the Sierra Nevada mountains in California around 20 years later. **James Dinneen**

Really brief



GUENTER FISCHER/IMAGEBROKER/ALAMY

Orange daisy lures flies by deception

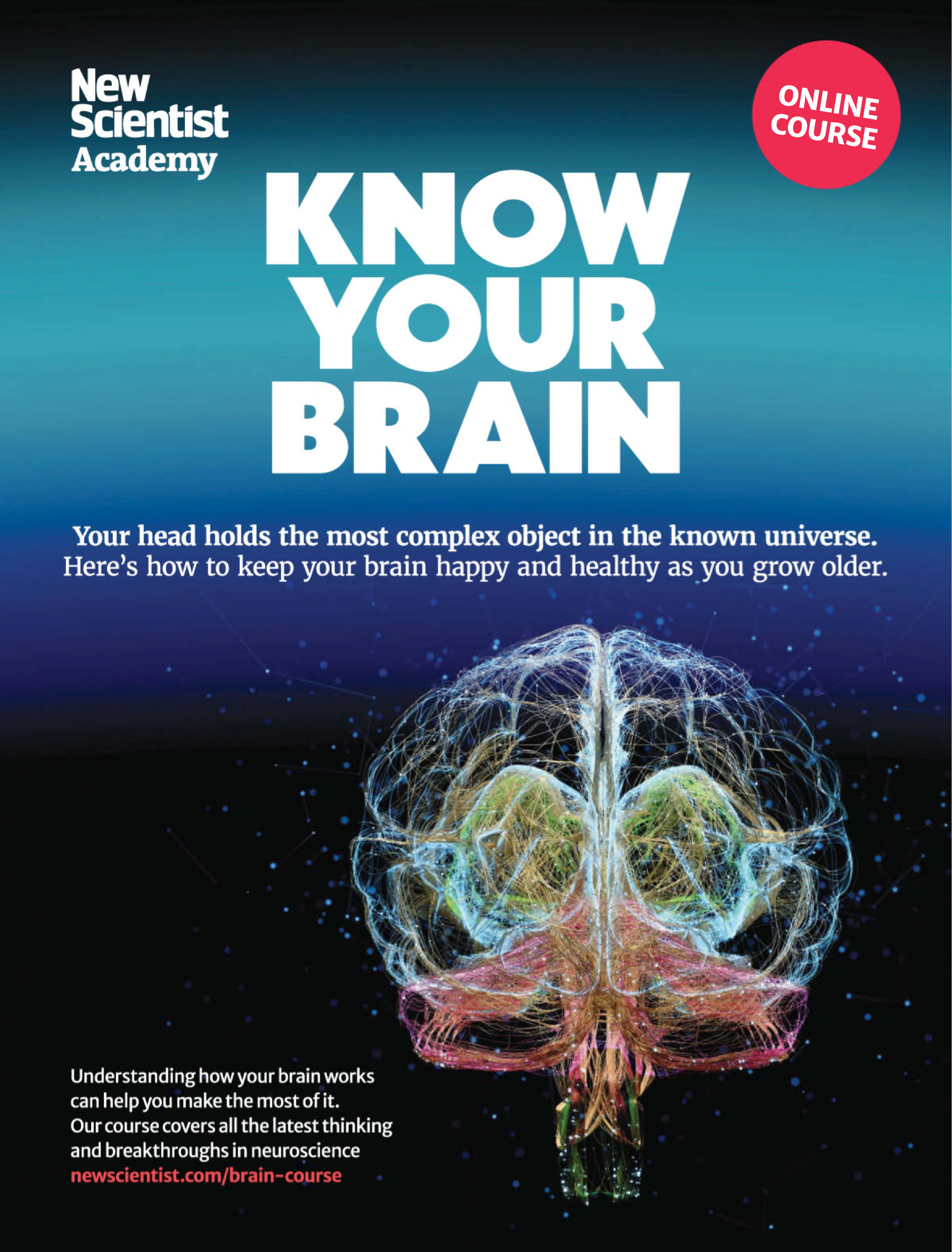
The orange-hued South African daisy *Gorteria diffusa* co-opts genes usually used to grow root hairs and transport iron to create petals that resemble female bee flies. Male flies land in hopes of mating, but end up ferrying pollen to other plants (*Current Biology*, doi.org/grzg58).

Recyclable plastic made from glue

A new type of plastic called poly(ethyl cyanoacrylate), or PECA, is easy to recycle and requires no fossil fuels to make it. A team used ethyl cyanoacrylate – the main ingredient in super glue – to create the plastic, which could potentially replace polystyrene (*Science Advances*, doi.org/grzg99).

Shocking bandage helps heal wounds

A stretchy bandage that can monitor wounds, release a drug as needed and perform electrical stimulation can accelerate healing. Rats wearing it had better healed wounds after 14 days than those that had no treatment, just electric stimulation or just the drug (*Science Advances*, DOI: 10.1126/sciadv.adf7388).


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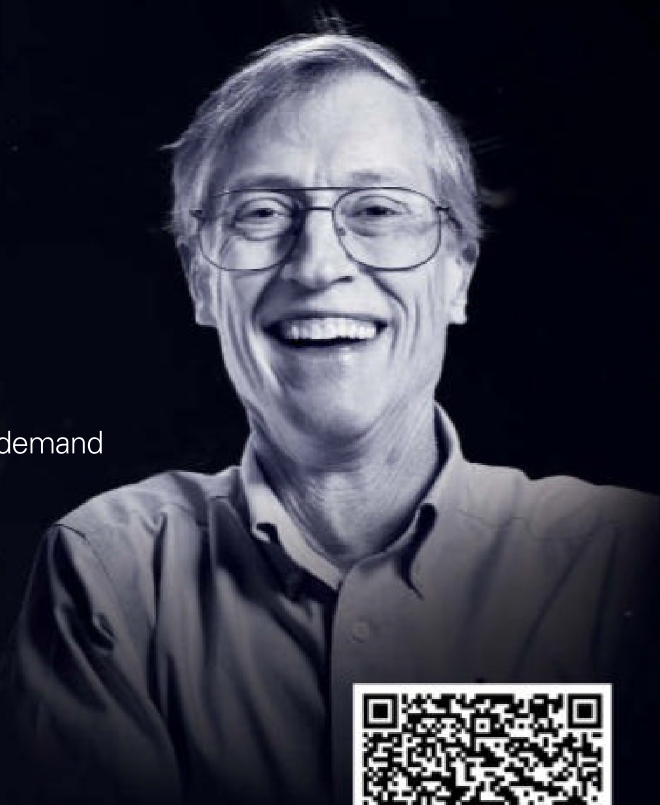
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Comment

Let them eat cake

We are trapped in a junk food cycle that is making us sick. The food system is broken, say **Henry Dimbleby** and **Jemima Lewis**

IN 1950, less than 1 per cent of the UK population was clinically obese. Today, that figure stands at 28 per cent. How did this happen? Did the British public suffer a massive collapse of willpower? Of course not. Humans haven't changed. The food system has.

Many people find it hard to imagine that a food "system" really exists, let alone that it could be shaping their own dietary habits. This is because we live deep in this vast, complex machinery of supply and demand, and struggle to see it as a whole. Our new book, *Ravenous*, aims to go behind the scenes: to show you how the system works, and your place in it.



MICHELLE D'URBANO

Let's start with one, crucial cog: the human appetite. Biologically, we are still hunter-gatherers. If you have to search for your food, it makes sense to prioritise things that will give you more calories than you expend. When we eat sugary, fatty foods, our taste buds respond with intense pleasure – a natural feedback mechanism to reward us for finding such a bountiful source of energy. This effect is strongest when sugar and fat are combined in a ratio of 2:1, the ratio found in breast milk.

It used to be hard work to find this kind of food. But in the second half of the 20th century, new methods of farming and manufacturing dramatically increased global food production. Since this "green revolution" in agriculture, highly calorific food has become so cheap and ubiquitous in much of the world it is hard to avoid eating it.

The green revolution has created an abundance of sugar, flour and vegetable oil. Companies heavily invest in developing and promoting foods made from these ingredients. They hack our appetite in foods like biscuits and cakes using the 2:1 ratio, knowing we find it irresistible.

Ultra-processed, packaged food now makes up more than half of the British diet – more than any other European nation. This kind of food contains little water and insoluble fibre, so it takes longer for us to feel full. As a result, we eat more of it and, because each mouthful is more calorific and less nutritious, it makes us fat and ill. Poor diet is now the biggest cause of avoidable illness and death in high-income countries.

In systems terms, we are stuck in a reinforcing feedback loop. Let's call it the Junk Food Cycle. We have a predilection for calorie-dense foods, which means food companies invest more in making and marketing these foods, which makes us eat more of them and expands the market. The food companies are trapped too. If they stop selling unhealthy foods, their shareholders will be angry.

We only need to look at the US to see where the UK is heading. Almost 70 per cent of US adults are now overweight or obese and life expectancy has been falling in recent years, in part due to the illnesses caused by junk food.

The UK is always quick to follow US trends, including the obviously destructive ones. The people living in the UK's most deprived areas – who tend to eat the most cheap, highly-processed food – are now starting to die earlier, and spend more of their lives in poor health.

There are two ways to escape this trap. The first is government intervention to rebalance the financial incentives in the system, such as taxing the sugar used in processed food. The second is to target human biology. A new kind of weight-loss drug, semaglutide, is proving effective at suppressing our evolved appetite. It is already used in the US and was recently approved for use in England, with the rest of the UK yet to announce their plans for it.

Such drugs can be a godsend for the severely obese. But they are a symptom of political failure. They wouldn't be necessary if politicians intervened at a systemic level. It is the food system that is making us ill, and it is the food system that needs curing. ▮

Henry Dimbleby and Jemima Lewis are authors of *Ravenous: How to get ourselves and our planet into shape*

Field notes from space-time

Why space scientists need science fiction

Carl Sagan's novel *Contact*, in which Ellie Arroway searches for alien intelligence, has been an inspiration and a guide, says **Chanda Prescod-Weinstein**



Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

Chanda's week

What I'm reading
Taylor Branch's 2000+ page trilogy about the US during the years of Martin Luther King, Jr.

What I'm watching
I saw the Apple TV adaptation of Isaac Asimov's Foundation *twice in one week!*

What I'm working on
My first PhD student will be defending his dissertation soon, so I am helping him get ready.

This column appears monthly. Up next week: Graham Lawton

THE only science fiction that ever really caught my attention when I was growing up, besides *Star Trek* and Robert Heinlein's *Stranger in a Strange Land*, was the novel *Contact* by Carl Sagan. When I was 15, I saw the 1997 film version of this, which he and his wife Ann Druyan had helped adapt for the screen. Later, as a 17-year-old navigating my first semester at university, I read the book, having accepted that I couldn't just read *Mansfield Park* on a loop for the rest of my life. *Contact* eventually became the gateway for me to try more popular science books, those written for general audiences.

Until that point, when it came to this genre, I had only read Stephen Hawking's *A Brief History of Time* – which inspired my interest in particle physics – and Dennis Overbye's *Lonely Hearts of the Cosmos: The story of the scientific quest for the secret of the universe*. Overbye's story was different from the usual public-facing science communications that I had been subject to because it told two stories: a scientific one and the human story that goes hand in hand with it.

The scientific question at the heart of the book was measuring the expansion rate of space-time at cosmological scales: how fast, exactly, were galaxies receding from one another? But equally interesting to me was the human story that underpinned this endeavour: the nasty fights the researchers got into with one another about their differing measurements.

The book terrified me – well, a bit. Luckily, I was young enough to believe that this kind of bitter competition was the purview of old men who were already dead or very soon would be. I won't argue that teenagers are the most tactful thinkers. And those of you who are familiar with my book, *The Disordered Cosmos*, know that I realise now that I was quite naive. In hindsight, maybe this was also one of the lessons I was supposed to draw from *Contact*, but, at the time, I wrote off the politics in this story as a government problem, not a scientist problem.

Instead, what caught my attention was the portrayal of Eleanor "Ellie" Arroway, a girl and then a woman who loved looking at the stars. Despite its apparently cynical (but in reality probably optimistic) portrayal of how the US government would respond to messages that contained details about how to build alien technology, *Contact* is, at its heart, a romantic story that shows off Sagan's unique gifts as a science communicator.

> **"I worked with data from the Very Large Array telescope used in *Contact*; it was exciting to be a real-life Ellie Arroway"**

Inspired by the Search for Extraterrestrial Intelligence (SETI) and real-life alien hunting astronomer Jill Tarter, Sagan tells a story that is focused on radio telescopes and takes advantage of the fact that the non-expert reader or viewer feels they understand these devices. By this I mean that even in the film, the adult Ellie (played by Jodie Foster) is seen listening to space using a pair of headphones connected to the Very Large Array (VLA) – a real facility in New Mexico.

In radio astronomy, scientists look at the cosmos using light waves that are in the radio wavelengths, the longest in the electromagnetic spectrum. These waves are longer than those of visible light that we can perceive with our eyes, and they are even longer than the infrared that we can see with night-vision goggles. Because radio waves are a type of light, they travel at the speed of light. Like other types of light, radio waves don't naturally produce sound, but with the right equipment, the electrical signals created by the detection of these waves can be converted into an audible mechanical signal.

Astronomers don't really do this for the purposes of actual research because there is rarely any point. This is the kind of detail that is unimportant for the purposes of the film of *Contact*, but how it portrays radio astronomy is one of the inaccuracies I occasionally hear scientists complain about. I was lucky enough to do some observations using the VLA for my third-year lab course. We were looking at the behaviour of water molecules in the Orion nebula: where they were, how fast they move and in what direction. We didn't listen to the data. Instead, we processed it so that we could look at it, just like we would with data from an optical telescope.

That was my favourite lab project and probably the only time I ever excelled in the lab; I was so excited to be a real-life Ellie Arroway. Later, I would be forced to think more about the human aspects of my experience. I would witness unnecessarily nasty arguments between scientists, complete with yelling and chalkboard punching. But, thankfully, Carl Sagan's *Contact* had not only introduced me to the idea of radio astronomy as a possible career path, it had also given me a road map for staying centred amid the chaotic collision of astronomical wonder and human politics. ▮

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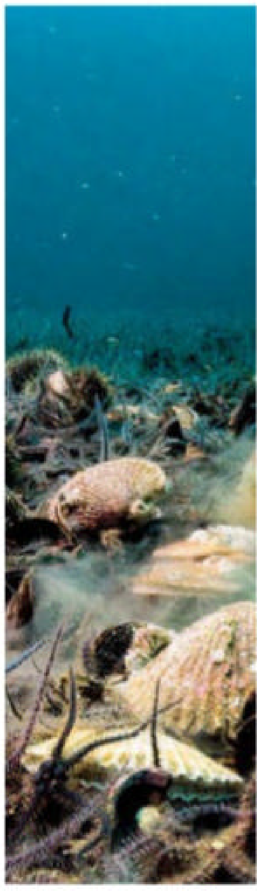




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JESSE WILKINSON

Wild beauty

Publisher: William Collins

WHEN David Attenborough says in his new documentary series, *Wild Isles*, that Britain is one of the most nature-depleted places in the world, his words resonate. Yet an accompanying book by Patrick Barkham and Alastair Fothergill brings together photographs that celebrate the stunning wildlife of Britain and Ireland. A reminder, perhaps, of the things we should cherish before it is too late.

Often seen in huge, shape-shifting flocks, starlings (top left) are actually in decline. To capture their nighttime roosting behaviour, the *Wild Isles* team deployed thermal cameras, with the birds' warmth causing them to show up in bright white. "There's something very Christmassy about it," producer Chris Howard said in the show, "all these trees festooned with light."

Great crested grebes, seen at top right during a courtship dance, were once hunted almost to extinction. Today, their numbers are on the rise, but changing weather patterns brought on by climate change made it difficult to predict and photograph this behaviour. "Ten, 15, 20 years ago, it would have happened almost like clockwork," Howard told *New Scientist*.

In the bottom row, starting at far left, two male adders battle for dominance, in the hope of securing a female. After sex, the males are dragged around by the female, bound together by dozens of penis barbs. The final three photos show: a grey seal sleeping vertically in the water, its nose poking out to breathe; a scallop escaping from a starfish by rapidly snapping its shell, creating a jet of water that propels it to safety; and a white-tailed eagle hunting a barnacle goose in Islay, Scotland.

David Stock

Editor's pick

On the true nature of the house cat

11 March, p 46

From Dawn Nelson, Greenwood, Maine, US

Many people discount the idea that cats can have emotional bonds with humans. Thus, in "The truth about cats", Michael Marshall suggests his cat may "just be looking for warmth", rather than cuddles.

Why are feline behaviours emotionally downplayed in this way? People don't do this with dogs (or other domestic animals for that matter). Consider this. Wolf pups lick the muzzles of adult wolves and this prompts adults to regurgitate food for the pups. Similarly, many dogs lick the faces of their owners. But I have yet to hear someone offhandedly comment: "Your dog isn't showing you affection, it just wants you to regurgitate food for it."

From Dave Riddlestone, Farnborough, Hampshire, UK

This article reminded me of the emotional attachments of a local cat. When we moved to our house, it lived in our garden and our neighbour's. Its owner had moved about 6 kilometres away.

She had taken the cat and kept it indoors for a few weeks because cats have a reputation of returning to their old house. As soon as it was let out, it came straight "home". She tried about four times with longer and longer lockdowns, but eventually gave up. The cat's attachment to "home" was stronger than to its owner.

From Susan Valdar, London, UK

I'm sure I won't be alone in congratulating you on taking the science of cat "ownership" seriously. Regarding the test on whether your cat can read your gaze, our cat Bertie understands the concept of following human gaze. He has long requested food close to mealtimes from people near his food bowl in the kitchen by using a particular procedure.

First, he delicately taps the foot of the "owner" who is present, using his claw to touch, but not scratch, our skin. When we look down at him, he makes eye contact, slowly turns his head to gaze at the clock on the wall and then turns back to make eye contact again. We feed him.

We assume he noticed that we look at the clock to check it really is his mealtime before we feed him.

From Gary Warburton, Dublin, Ireland

You wonder if affection in cats is, in fact, cupboard love. When I go out, my cat waits for hours by my front door, with much vocalisation and rubbing when I return, but it's not for food. There is untouched food in her bowl. She also sleeps beside me on the couch with one paw touching me and wakes if I move. Surely this is separation anxiety. My mother's cat has the same sort of bond with her.

I have noticed that cats seem to only have this sort of bond with one particular person, which is different to the human-dog dynamic and may explain the perception by non-owners that cats are less sociable than dogs. I don't think you can study cat sociability using someone else's cat.

One way to meet the 2000-watt challenge

11 February, p 36

From Vernon Hockley, Great Barrow, Cheshire, UK

On the subject of the 2000-watt energy-saving challenge, we consume energy at the rate of 12,000 kilowatts per year to run our house of five people and charge an electric car.

This equates to a rate of energy use of 1400 watts an hour. We have no gas, just a ground source heat pump and solar panels. Two of us are retired and are at home often during the day. The heat pump provides a uniform temperature 24/7. Our energy use leaves scope in the 2000-watt target for energy related to food production.

All hail your explanation of strange liquid sponges

11 March, p 43

From HildaRuth Beaumont, Brighton, East Sussex, UK

Liquid sponges are counter-intuitive in the extreme, yet Katharine Sanderson manages to describe what is going on at the molecular level in these new materials in a completely comprehensible way. She achieves this by using analogies with everyday objects that we all understand – doughnuts, pasta, dinner plates. As a one-time secondary school chemistry teacher, I am full of admiration.

Data will shift the dial in the clean river campaign

11 March, p 8

From Andrew Shead, Tulsa, Oklahoma, US

Jamie Woodward is quite correct. Better data on the state of rivers would forcefully multiply the sound and fury over pollution.

Data collection and analysis should be independent. Sampling can begin where each river rises, continuing at 1-kilometre intervals downstream. Sample collection could be done by drones that return to the same spot each time. Analysis should be automated to reveal the spectrum of pollution. In time, a compelling set of data would show where it is happening, identify the pollutants and enable the source of pollution to be located. With data like that, we could pillory government and polluters both.

Stone Age cave art is a wonder in many ways

18 March, p 38

From Alex Bowman, Glasgow, UK

"Messages from the Stone Age", about hand stencils found in caves and early human culture, brings to mind 16,500-year-old cave paintings in Lascaux, France. These are said to show the constellation Taurus as a bull with the Hyades star cluster as the face and, above it, the Pleiades, as well as other stars. Such art also suggests a widespread early culture.

Good governance of nature is possible

Letters, 25 February

From Ton Smit, Utrecht, The Netherlands

James Fradgley thinks that the Judaeo-Christian idea of having dominion over nature is the biggest problem in how we regard nature as mere property.

Dominion in itself isn't the problem, rather the greed and indifference that makes people "use" nature for their own ends. There is such a thing as good governance. I am a Christian and I have never seen nature as property. I have always regarded myself as a visitor in a world of beauty.

The dog-human bond is a mutual one too

4 February, p 44

From Markus Eymann, Edmonton, Alberta, Canada

Your story claims that mongooses and warthogs provide the only example of mutualism between two mammal species. Hang on, what about dogs and humans? We provide food and a warm place to sleep. They help us hunt, herd our sheep, protect our property, guide those who are blind, offer comfort, give older people a reason to go for a walk, and play fetch. Sounds like mutualism to me.

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Clare Wilson

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Building your digital twin

It would be the ultimate in personalised medicine: a virtual "you" with which doctors could predict your health. But is it possible, asks **Claire Ainsworth**

Book
Virtual You
Peter Coveney and Roger Highfield
Princeton University Press

IMAGINE a future where science has created your twin. Not a flesh-and-blood twin, but one that recreates your flesh and blood, your bones, your heart, your brain – your whole body, in fact – as an exquisitely sophisticated computer model.

Your doctors can use this digital twin to work out how you will respond to a particular drug or medical procedure. They can even look further into the future, creating a "healthcast", a bit like the medical equivalent of a weather forecast, to predict what diseases might befall you or how your lifestyle will affect your health as you age. It is the ultimate in personalised medicine.

This is the bold vision set out in *Virtual You: How building your digital twin will revolutionize medicine and change your life* by Peter Coveney, director of the Centre for Computational Science at University College London, and Roger Highfield, a former science journalist (and editor of *New Scientist*) who is now science director of the Science Museum Group, UK.

At its heart is the seismic shift under way in biomedical science as it strives to move from being a largely descriptive, experimental science to one that uses mathematics to achieve the kind of predictive power and deeper mechanistic understanding that could revolutionise medicine.

Virtual You's scope is as epic as its vision, taking us through medical history from Vesalius to Venter, and from the Antikythera mechanism to supercomputers and beyond. This means the concepts come at you thick and fast, although as a non-mathematician, I found the explanations refreshingly clear.



A person interacts with their digital twin in Hangzhou, China

CFOTO/FUTURE PUBLISHING VIA GETTY IMAGES

"Imagine all the parts that come together to make you work. Now, imagine trying to create a model of this"

Digital twins are already in widespread use in industries such as civil engineering. But these model systems are, relatively speaking, much simpler than the dizzyingly complex human body. Imagine all the parts that come together to make you work: from the 3 billion letters of your genome, the myriad molecules that make up your cells, the trillions of cells building your tissues and organs, and the environment having its input too. Now, imagine trying to create a model of this that is tailored to each unique individual and that predicts the changes that will take place over a lifetime.

Coveney and Highfield set out the challenges in the first four chapters, outlining the key components that need to come together to build a virtual you. The first one, data, is in no shortage, although we still need more. But scientists need new theories to make sense of this data and to convert it into mathematical understanding.

This is easier said than done. Changes in the systems biologists want to describe usually aren't in direct proportion to one another, a property mathematicians describe as "non-linear". Another complication is "emergence", where the whole of a system is greater than the sum of its parts.

This complexity challenges mathematics and pushes computing to the limit too. By the end of chapter four, the reader is wondering whether it is, in fact, remotely possible. But having shown us what we are up against, Coveney and Highfield reveal the remarkable progress that has already been made at multiple levels of biological organisation, from Coveney's own work on stimulating the molecular biology of HIV infections, to predicting whether drugs will harm heart tissue, to attempts to model whole bacterial cells.

There is an astonishing account of how scientists have built a model for the whole heart, not only shedding light on conditions such as arrhythmias and heart failure, but also to start tailoring treatments to individual patients. Researchers are also creating models of other organs, like the lung and brain, and even starting on organ systems, such as the cardiovascular system.

But getting to the next level – a whole human individual – is going to require yet more data and a revolution in computing technology far beyond what is currently possible. Whether we will get there is an open question, but *Virtual You* shows us what scientists from widely differing disciplines can achieve when they all work together.

Claire Ainsworth is a science journalist based in Hampshire, UK

Ghosts in the brain?

Many people feel an uncanny "presence" when no one is there. **Jason Arunn Murugesu** probes a lively book that asks why

Book

Presence

Ben Alderson-Day

Manchester University Press

THE idea that we experience ghostly presences through sensory phenomena is as old as time. But for some time now, we have accepted that many people hear voices, see unexplained phenomena and experience presences for which there is no rational account.

So how do we explain them? What do they tell us about how the human brain is wired – or what we mean by the concept of "self"? These questions have preoccupied Ben Alderson-Day, a psychology researcher at Durham University in the UK, for most of his career. In his first book, *Presence: The strange science and true stories of the unseen other*, he sets out to provide a comprehensive account of what we know so far.

Early on, we meet two young men who hear voices. Those voices differ in many ways, but both report feeling a presence that is hard to describe. To Alderson-Day, it sounded almost like a "haunting", a feeling of someone looking over their shoulder.

The pair, Alex and Daniel, are struggling with their mental health. But this experience of a presence affects many other people in different circumstances: for example, during explorer Ernest Shackleton's efforts to save his crew after a failed attempt to cross Antarctica in 1914.

After many misadventures, including leaving most of his crew on Elephant Island off Antarctica. Shackleton and five others set off by boat to find help at whaling stations on South Georgia, an island in the south Atlantic Ocean. Landing on the wrong side of the island, Shackleton decided to trek north to the stations with the only two men who were fit enough to go.

The three would later describe a fourth person who was with them on the final, perilous leg of the ultimately successful rescue. One of them, Frank Worsley, wrote: "Of course, there were only three, but it is strange that in mentally reviewing the crossing we should always think of a fourth… then correct ourselves."



Ernest Shackleton's rescue mission lands in 1916. Some crew later felt an "extra" presence

SCIENCE HISTORY IMAGES/ALAMY

Alderson-Day doesn't pretend to know what the trio saw on their journey, but he uses this example to thread together the strange phenomena experienced by all sorts of people in extreme situations.

What happened to Luke Robertson, the youngest Briton to ski to the South Pole alone, sounds like a rerun of Shackleton. But this time there were two "presences", with voices, who – together and in very different ways – pushed and pulled the young skier to his goal.

Driving the brain and body to the brink, whether in extreme temperatures, via physical exertion or through a dangerous lack of sleep, appears to be a common thread. Robertson and many of the other people in *Presence* describe strange visions – some are rooted in their memories, while others seem completely unrelated to their lives.

Hearing voices is widespread, points out Alderson-Day: 5 to 15 per cent of adults hear voices at some point in their lives. For those experiencing distress from the presences they experience, he describes new treatments. Virtual reality is now being used to make voices less disturbing. AVATAR therapy, developed at King's College London, lets the voice-hearer and a therapist co-create a computer-based avatar of the distressing voice. So far, the results seem promising.

Throughout his book, Alderson-Day tries to find a unifying theory, but he knows there is a good chance that no such idea exists – or not yet. Instead, he does a valiant job of rescuing the phenomena from simple relegation to brain malfunction.

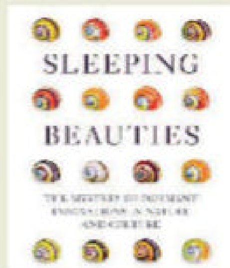
Presence is a fascinating read. The writing is lively and the stories are compelling. Thanks to Alderson-Day, the mysterious world of visions, voices and ghostly presences is just that bit more understandable. ■

Don't miss



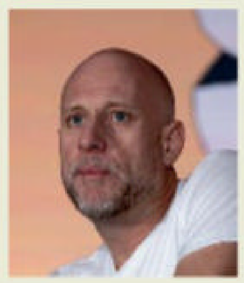
Visit

Titanosaur: Life as the biggest dinosaur will be looming large at London's Natural History Museum until 7 January 2024. Prepare to gawp: *Patagotitan mayorum* was four times the weight of the museum's *Diplodocus*, Dippy.



Read

Sleeping Beauties are dormant innovations in nature and human history, such as prehistoric bacteria with the ability to fight off modern antibiotics. They are investigated here by evolutionary biologist Andreas Wagner. Out on 6 April in the UK and US.



Listen

How to Fix the Internet, the Electronic Frontier Foundation's podcast, recently aired a chat with artist Trevor Paglen (pictured). His art creates a physical manifestation of today's internet, so tomorrow's can be better.

STALE GRUT, MEF

Maths by the book

An engaging read about how central mathematics is to literature by authors from George Eliot to Georges Perec is a homage to both subjects, finds **Tom Tierney**

Book

Once Upon a Prime

Sarah Hart

HarperCollins (UK, out 13 April) and Macmillan (US, out 11 April)

DID you know that cycloids, the curves traced by a point on a circle as it rolls along a straight line, appear in *Moby-Dick*? Or that Leo Tolstoy made extensive use of calculus in *War and Peace*? Or that George Eliot talked about taking "a dose of mathematics every day" and that this interest is central to her novel, *Daniel Deronda*?

These are just some of the stories you will come across in *Once Upon a Prime: The wondrous connections between mathematics and literature*. Sarah Hart, a mathematician at Birkbeck, University of London, traces mathematical references in literature going as far back as Aristophanes in 414 BC, and argues that we should see mathematics and literature as complementary parts of the same quest for an understanding of human life and our place in the world.

Georges Perec would doubtless agree. He was a member of the France-based Oulipo group that deliberately set out to work within mathematical constraints, and his most famous work was a novel – *La Disparation* – written entirely without the use of the letter "e". Of course, the question has to be asked whether such restrictions add to the quality of the literature.

I recently enjoyed Amor Towles's *A Gentleman in Moscow*, in which we revisit the protagonist in his hotel at time intervals that double and then, at the halfway point, begin to halve. But I didn't notice this pattern as I read the book and I can't imagine many do. So was it there just for the writer's private entertainment?



CPA MEDIA PTE LTD/ALAMY

Maths is woven into *Moby-Dick*, about the hunt for an elusive whale

Hart quotes Perec saying that mathematical constraints helped to stimulate his creativity. This point is echoed by Towles, who says that rules – even artificial ones – can aid a writer, in much the same way that the rules relating to a sonnet can help a poet.

Hart covers a lot of ground. In one section, we get a detailed and amusing analysis of the various giants and little people that have appeared in stories over the years, from *Gulliver's Travels* to *The Borrowers*. Most giants would have collapsed under their own weight, apparently, whereas the tiny Lilliputians Gulliver met would have been surprisingly strong.

It isn't entirely convincing that this section covers a key link between maths and literature. Likewise, the discussion of the prominence of the numbers 3, 7 and 12 in fairy tales. But elsewhere, Hart makes a compelling case. The significance of maths to Lewis Carroll is no surprise – the author of *Alice's Adventures in Wonderland* was a renowned mathematician – but Hart shows us how deeply it was woven into his fiction.

Overall, the book isn't overly academic. It allows itself moments of levity and is engaging, permeated with a love of good writing as well as good maths. Perhaps that is how it should be read: as a homage to both. ▮

Tom Tierney is a writer based in Dublin, Ireland

Timing a bit off in dino thriller

Film

65

Scott Beck and Bryan Woods

On general release in cinemas

AFTER an asteroid hits his spaceship, astronaut Mills (Adam Driver) crash-lands on Earth while transporting a cargo of intergalactic voyagers kept in cryosleep. But this turns out to be Earth 65 million years ago and, alongside the only other survivor, a young girl named Koa (Ariana Greenblatt), Mills must stay alive in a prehistoric world populated by killer dinosaurs.

That is the premise of *65*, a new film written and directed by Scott Beck and Bryan Woods that throws up a number of issues – starting with its title, which is intended to refer to the number of years (in millions) since the end of the Cretaceous period. The problem is that, in 2012, the International Commission on Stratigraphy revised the end of the Cretaceous to around 66 million years ago, not the 65.5 million years previously posited. So, if Driver's character had landed 65 million years ago, there would have been no dinosaurs to grapple with, given this period concluded with a huge asteroid impact that wiped out these reptiles.

65 is also a film with a case of identity crisis. Often let down by a jarringly slow-paced narrative, it doesn't know what kind of sci-fi movie it wants to be. It is neither exciting enough to be a survival thriller, nor playful enough for a bona fide family adventure.

Despite dealing with some promising, soul-searching ideas relating to grief and parental guilt, the writers opt for the worst kind of preposterous denouement. This film is only about 90 minutes long, but it felt like 3 hours had passed by the time it had ended. ▮

Linda Marric



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The truth about wrinkles

Far from being a purely cosmetic concern, wrinkles may be a driver of ageing in the body and brain, finds **Graham Lawton**

ON HER 120th birthday, Jeanne Calment – generally regarded as the oldest person ever to have lived – proved she still had her wits about her: "I've only got one wrinkle," she wisecracked, "and I'm sitting on it."

Funny, but untrue. The Frenchwoman was, by then, extremely wrinkly. On the Fitzpatrick Wrinkle Scale, she would have been a shoo-in for the top category, with deep wrinkles and discoloured skin that had lost its elasticity. *Quelle surprise.* She may not have been as old as she claimed, but she was at least 97. Anybody who lives to 100 or so can expect the same.

Historically, this has been regarded by many as a purely cosmetic problem. Wrinkles, sags and bags are, in some cultures, considered unsightly or an unwanted sign of how old we are. Right or wrong, that has led to a centuries-long battle to fill them in or smooth them over.

More recently, however, the war against wrinkles has moved onto a more urgent footing. Aged skin is much worse than young skin at all the vital things it does to help maintain your health. Moreover, emerging evidence suggests that, as skin ages, it releases a chemical cocktail around the body that could drive premature ageing of other organs. "If your skin is getting older, you are getting older inside, so be careful," says Cláudia Cavadas at the University of Coimbra, Portugal. In other words, wrinkles may not just be a result of ageing, but also a driver of it. Which begs the question: could our fight to banish wrinkles help reverse the clock both inside and out?

The skin is the largest organ in the human body. Its main job is to act as a barrier between the inner and outer world, but it has many other functions too. It has a role in our immunity, it generates vitamin D, acts as a regulator of body temperature and water balance, is a rapid responder to minor wounds and a producer of the pigment melanin.

Skin consists of two main layers, an outer one called the epidermis and the dermis that sits below it. Sandwiched between them is the dermal-epidermal junction, which anchors the layers together and is important for maintaining the skin's structural integrity.

The epidermis is one of the first lines of defence against the hostile outside world. Its surface is a tessellated layer of dead cells forming a tough, waterproof and flexible shell, replaced continuously from a sheet of stem cells below. The epidermis is rich in hyaluronic acid, which destroys harmful compounds called free radicals generated by normal cell metabolism.

The dermis is mostly made of connective tissue – largely the proteins collagen and elastin, which make tissues strong and able to withstand stretching – but also contains cells called fibroblasts, which secrete collagen, elastin and hyaluronic acid and play a critical




KWANGMOOZAA/MYILLO/JACOBLUND/ISTOCK

role in wound healing. Hair follicles are rooted in this layer, as is the skin's blood supply.

As skin ages, it degenerates dramatically. In the epidermis, stem cell proliferation slows down, leading to progressive thinning – we lose up to half this layer over our lifetime – and a roughening of its surface. The glue that sticks the cells together weakens and the water and fat content decreases. This contributes to deepening of folds that run from the nose to the mouth, makes the cheeks appear deflated and can create hollowing around the eyes and heaviness in the jowls.

In the dermis, fibroblasts decline in number, resulting in faltering production of collagen, elastin and hyaluronic acid and a marked thinning of this layer too. The dermal-epidermal junction also starts to crumble, reducing the skin's integrity. Together, this all contributes to further wrinkling and sagging.

Zombie cells

On top of this, as skin ages, more and more cells enter a zombie-like state called senescence. Such cells have endured some sort of irreversible damage and need to be eliminated, but, in the meantime, remain alive and metabolically active, though they no longer divide. Senescence, which occurs throughout the body, is initially protective because it prevents DNA-damaged cells from becoming cancerous. Yet as time marches on, the mechanisms for clearing senescent cells out start to decline and they build up in tissues.

This is bad news, as the cells pump out a toxic cocktail of inflammatory proteins that damage surrounding cells and connective tissue. The build-up of these cells has been shown to be a direct cause of some of the conditions that are generally more common in older age, including cataracts, cancer, clogged blood vessels, type 2 diabetes, osteoarthritis, Parkinson's disease and Alzheimer's disease. The build-up of senescent cells also correlates with defects in elastin and increased wrinkling.

The problems stemming from senescent cells are an inevitable result of the ageing process, but in the skin, they are exacerbated by external forces such as pollution, smoking, poor diet and, worst of all, sunlight.

Exposure to ultraviolet (UV) in sunlight causes a phenomenon called skin photoageing, which accelerates the natural ageing processes. There are two types of UV ›

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MICHAEL DUNNING/GETTY IMAGES; TOP RIGHT: MICHELLE ARNOLD/ALAMY

radiation. UVA penetrates the epidermis and dermis, damaging both; UVB only goes as deep as the epidermis. Both degrade collagen and elastin, which become disorganised and fragmented, leading to deep wrinkles and sagging. Even though natural ageing thins the skin, photoaged skin is thickened, which accentuates the appearance of wrinkles. UV also causes DNA damage to skin cells of all types, which accelerates their progression towards senescence.

The classic illustration of photoageing is a striking photograph (below right) published in the *New England Journal of Medicine* in 2012 of William McElligott, a 66-year-old truck driver who spent 28 years delivering milk around Chicago. The right side of his face is relatively free of wrinkles, but the left side – which faced the window of his driver's side door – is thickened, sagging and deeply wrinkled. "The skin is older in the part that was more exposed to the sun," says Cavadas. "It highlights the importance of skin protection."

This isn't just because it prevents cosmetic wear and tear and the risk of skin cancer, but also because evidence is building that "skin age" is correlated with general health, longevity and risk of death.

Showing your age

In 2013, a team from Unilever and several universities reported that the extent of facial photoageing in people in their 60s was correlated with the risk of cardiovascular disease, a classic health condition of older age.

Another study, from 2015, found that the perceived age of people in their 70s from photographs taken in 2001 was a good predictor of their likelihood of dying over the following 12 years. A more recent paper reported that older people who look facially younger than their actual age were significantly less likely to have cataracts, osteoporosis, age-related hearing loss and chronic obstructive pulmonary disease, and also had better overall cognitive functioning.

This is perhaps no surprise, as we know that people age at different rates and there can be a mismatch between chronological age – the number of years on the clock – and biological age, which is a measure of how far our bodies have descended down the slippery slope of the ageing process.

But Cavadas thinks it goes deeper than this. In an opinion piece last year, she and two colleagues proposed that skin ageing is a driver of whole-body ageing.

The hypothesis centres on senescent cells and their toxic leakages, known as the SASP (senescence-associated secretory phenotype). These include inflammatory proteins, compounds that affect the immune system, and protein-destroying enzymes. It is already well-established that senescent cells in one tissue can damage healthy cells in another, says Cavadas, and that the SASP is a leading cause of inflammaging, the low-level chronic inflammation that creeps throughout our bodies as we age and is linked with health conditions.

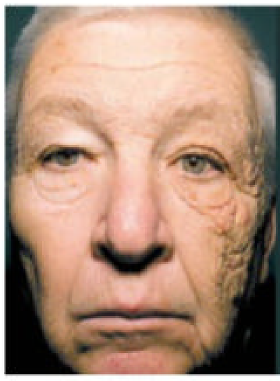
Cavadas put two and two together. Aged skin – especially when it is prematurely aged by UV damage – carries a heavy load of senescent cells. The blood vessels in the dermis could carry the cells' toxic cocktail far and wide.

To find out if premature ageing really is triggering more widespread ageing throughout the body, Cavadas is initially exploring possible links between the skin and parts of the brain, in particular the hypothalamus and hippocampus. The former is a small region that controls many basic life-support functions, including metabolism, sleep, hunger, growth, reproduction and homeostasis, which is the body's ability to maintain a steady state while still being able to adapt to change. The hypothalamus receives signals from far-flung parts of the body including the skin. The hippocampus, meanwhile, is involved in memory formation and is one of the first brain regions to be affected by dementia.

The hypothalamus has emerged as a critical node in the ageing process, says Cavadas. "The hypothalamus has several important functions that we know become dysfunctional in ageing," she says. Mice engineered to have fewer stem cells in their hypothalamus age faster and die younger, while middle-aged mice given implants of healthy, young hypothalamic stem cells live longer. Ageing hypothalamuses also secrete less gonadotropin-releasing hormone, which is involved in triggering the secretion of sex hormones, and older mice in which this decline is halted show improved skin condition.

The hippocampus receives messages from the skin too. In mice repeatedly exposed to high levels of UVB radiation, the hippocampus reduces its proliferation of new cells and the

> **"Wrinkle treatment should no longer be seen as a vanity project, but as a vital part of staying biologically young and healthy"**



NEJM

The left side of William McElligott's face was exposed to more sunlight due to his job as a delivery driver





Left: UV rays from the sun age skin prematurely and make it more prone to cancer.
Right: Collagen supplements can delay wrinkling

mice exhibit depression-like behaviour. This suggests there is an intimate link between the skin and the brain, which Cavadas calls the skin-brain axis. But she stresses that the idea of skin senescence contributing to hippocampal and hypothalamic dysfunction via the SASP, driving whole-body ageing, is still only a hypothesis.

Janet Lord at the University of Birmingham, UK, says the idea that ageing skin can cause problems around the rest of the body is sound, although evidence of a causative link is needed.

Cell destroyers

Cavadas hopes support for her idea may come from experimental drugs called senolytics, which destroy senescent cells, and senomodulators, which don't kill the cells but stop them from dripping their poison. These drugs – collectively called senotherapeutics – are already in clinical trials for many age-related conditions and could be available as skin creams in as little as three years, says Cavadas.

Experimental evidence suggests they will be safe and effective. In 2019, researchers mainly at Drexel University College of Medicine in Philadelphia, Pennsylvania, applied a drug called rapamycin, which is a senomodulator as well as a promising inhibitor of ageing in general, to the photoaged skin of a handful of male and female volunteers aged over 40. The drug reduced markers of cell senescence, increased the amount of collagen in the dermis and improved the skin's appearance. Another small experiment did the same with metformin, another senomodulator, and found that it reduced the damage of photoageing in mice. Using a senolytic to eliminate senescent cells from mouse skin increases the proliferation of hair follicle stem cells, which also suggests a partial reversal of the ageing process.

To support her own hypothesis around wrinkles driving whole-body ageing, Cavadas is planning to test senolytics on animal models of aged skin to identify the effect they have on markers of brain health in the hypothalamus and hippocampus. "The evidence is still fragile, but, in a year, we will have experimental data," she says.

"Overall, topical, and possibly oral, senotherapeutic treatments have tremendous potential to eventually become a standard of care for skin ageing," says Paul Robbins at the University of Minnesota's Institute on the Biology of Aging and Metabolism. But they will have to get through clinical trials, says Cavadas, and we can't expect miracles. "If you stop all the senescent cells in the skin, the rate of ageing will be at least diminished. I won't say rejuvenation," she says.

Whether reversing skin ageing reverses whole body ageing will need to be seen. But there is another good reason to want to slow it down. Aged skin is worse than young skin at pretty much everything it is supposed to do, says David Zargaran, a plastic surgeon at the Royal Free Hospital, London. Its barrier functions weaken, wounds are slower to heal, sensitivity to touch declines and its immune defences are compromised. Aged skin is also more prone to cancer.

While we wait on senotherapy, what are our options? Many bathroom cabinets are already full of anti-wrinkle creams, some costing skin-sagging sums of money. These may well reduce the appearance of wrinkles, but, at present, there is limited evidence that they are genuine anti-ageing treatments, says Zargaran.

Yet there is something that is proven to work, cosmetically at least. According to Hend Al-Atif at King Khalid University in Abha, Saudi Arabia, collagen is a paradigm-shifting innovation. A review published last year on topical and oral collagen supplements shows that both are useful for delaying the wrinkling process by plumping up the dwindling connective tissue. Oral supplements are usually composed of collagen from marine fish, a byproduct of the fishing and aquaculture industries, which has been chopped up into small pieces so it can be absorbed by the gut. These treatments, however, do nothing to tackle senescent cells.

We do, however, have one method for preventing skin ageing already in our cupboards: sunscreen, which absorbs UV rays before they do damage to the skin. It is never too soon to start. Even though the first visible signs of skin ageing usually don't appear until our mid-20s, the underlying processes are under way much earlier. Last year, an international team of researchers studied skin ageing in Asian women aged between 18 and 24 and reported that many already perceive subtle signs of facial ageing: dull skin, uneven tone, dryness, wrinkles and a lack of firmness.

Which all goes to show that wrinkle treatment should no longer be seen as a vanity project, but as a vital part of staying biologically young and healthy. Everyone should pay attention to that, because we all have skin in this game. ▮



Graham Lawton is feature writer at *New Scientist*

Head in the clouds

In a lifetime of tree climbing, **Nalini Nadkarni** has led the way in discovering the secrets of cloud forest biology. Interview by Matthew Ponsford

WHEN Nalini Nadkarni first ventured into the canopy of a cloud forest, almost nothing was known about this unique ecosystem. To explore it, she and a small group of pioneers had to develop special tree-climbing techniques, which, over the intervening four decades, have allowed her and others to unlock the mysteries of forest canopy biology. Monteverde in Costa Rica, where Nadkarni does much of her fieldwork, is home to some remarkable species, including the resplendent quetzal. But it turns out that the entire ecosystem depends on a more modest and unlikely group of organisms called epiphytes. These tree-dwelling plants – which include a dreamy array of wonders from ephemeral mosses that drip off branches and luscious ferns that nestle in crevices to a dazzling variety of orchids – act like nutrient sponges, extracting chemicals from mist and rain and conveying them to the forest floor.

Seven years ago, Nadkarni, who is at the University of Utah, fell from the canopy and broke her back in five places. Nevertheless, she was back in her tree-climbing harness a couple of years later. Such grit is a hallmark of her career, which, as well as reaching the forest heights, has taken her to some other unusual places. As a self-professed secular "missionary" for ecology, she has worked with prisoners to breed threatened plants and animals, and has delivered sermons in churches and synagogues. Now, aged 68, Nadkarni acknowledges that her tree-climbing days are nearing an end. But she also knows that climate change poses unprecedented challenges to cloud forests and is determined to document how it is affecting the epiphytes on which they depend.

Matthew Ponsford: When did you realise that you wanted to explore the forest canopy?

Nalini Nadkarni: When I first came to Costa Rica in the summer of 1979, it was clear to me that there was so much action going on up there, with the howler monkeys and bird flocks, and plants growing too. But when I asked my professors "What's going on in the canopy?", they said: "Well, we don't really know much about it. We don't have a way to get up there safely or non-destructively." So, I thought, if a scientist is supposed to be exploring the unknown, it seems like the canopy would be a really important place to look.

How did you set about it?

Many tropical trees have noxious insects or big thorns on their trunks, or their first branches are 100 feet above the forest floor. So you can't rely on the old childhood method of just throwing your leg over a lower branch and making your way up. In Costa Rica, I encountered a graduate student named Don Perry, who was one of the true pioneers of canopy research in the lowland rainforests at La Selva Biological Station. To rig trees with climbing ropes, he would first shoot up a 20-pound fishing line with a powerful crossbow. The arrow goes up and over the branch and then comes back down to the forest floor. But this was 1979, when the Nicaraguan Sandinista rebellion was going on, so customs officials were not very happy about my bringing a crossbow from the US to Costa Rica.

I ended up inventing an alternative I called the Master-Caster, which is a short, aluminium rod with a slingshot mounted on one side and a fishing reel below it. I follow the same protocol: shoot a fishing line over a branch, use that to pull over a parachute cord, then a climbing rope. After that, it's standard mountain climbing gear: harnesses and ascenders that clamp onto the rope.


NABIL NEZZAR

What is it like up there?
You're sitting on a branch high above the forest floor and you get the sense of being in the middle of this three-dimensional volume of a thousand-thousand leaves all moving. You see bromeliads and orchids and ferns and hemi-epiphytes like strangler figs, just covering these branches and trunks – all are canopy-dwelling plants that you never encounter on the forest floor. You almost feel you're in an open field because you are above the foliage where photosynthesis is going on, where pollination is going on, where fruit dispersal is going on.

What did you learn on those early explorations?
It was like doing 19th-century biology, being Alfred Russel Wallace or Alexander Humboldt. The first 20 years of canopy research were almost entirely descriptive and observational. We found that there's canopy soil that accumulates underneath these living mats of canopy-dwelling plants, and asked how it compares to soil on the forest floor. We asked who's pollinating this bromeliad and who's dispersing the fruits of this ericaceous shrub. As we started documenting patterns, we began generating ideas about the processes that determine these distributions. Is there more mist and fog at the edge of the canopy, and is that going to foster a different set of plants? We began to understand the importance of epiphytes as a keystone to this whole system. We began looking at processes of regeneration by removing epiphytes from some branches and learned that it takes over four decades for them to grow back. In the 1990s, we finally started being able to make predictions.

One crucial prediction is how climate change will affect epiphytes. What are you finding?
Right now, I'm working with three colleagues: Sybil Gotsch, a plant ecophysiologist from the University of Kentucky; Todd Dawson, who is a plant physiologist at the University of California, Berkeley; and Lauren Lowman, an ecological modeller at Wake Forest University, North Carolina. All four of us are trying to document the effects of climate change on tropical montane forest canopy communities. They're called cloud forests because, over evolutionary time, they have been inundated by wind-driven mist and cloud for much of the year. But as land and sea temperatures warm, the cloud bank is lifting. Epiphytes – these canopy-growing plants – don't have roots that go into the ground or into the trees, so they get their nutrients and water from this incoming mist and cloud and rain. As the cloud lifts, it is pinching the hose not only of moisture, but also of nutrients into cloud forests.

We're predicting that will have a negative effect on canopy-dwelling plants. We can see that already. Of course, there's a lot of variability – some years, there is more rainfall than others – but the general trend is definitely indicative of what has been predicted by global climate change models over the past 20 years. And we anticipate that if we don't stop pumping carbon dioxide into the air, the trends are going to continue and, if anything, worsen.

How has Monteverde changed since you began your research there?
If you pop up into the canopy and look around, it looks pretty similar. But look at the landscape below and you see more human use of the forest, more trees being cut to make pastures, more isolated trees. We're trying to figure out whether we can make predictions

"You're sitting on a branch high above the forest floor. You almost feel you're in an open field"





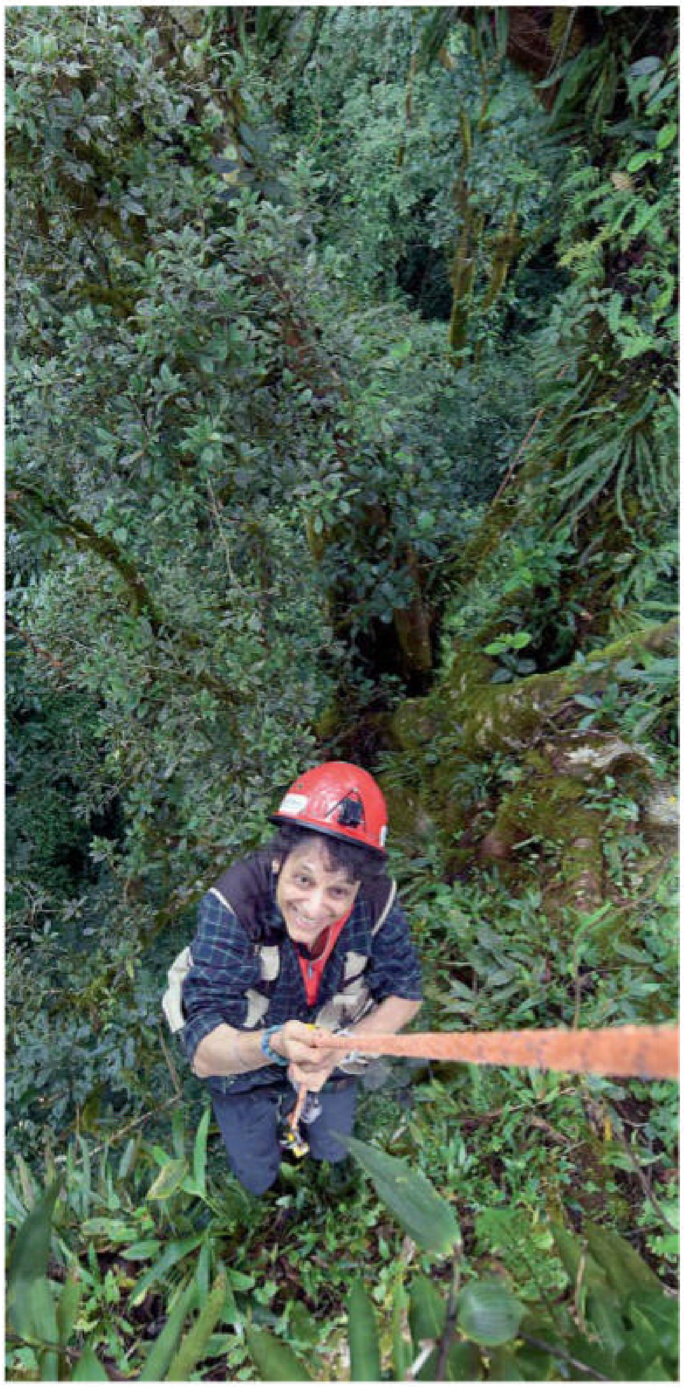
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Nadkarni helped to design the TreeTop Barbie doll





CHRISTIAN SINIBALDI

At 68, Nadkarni is still using the tree climbing techniques she helped pioneer four decades ago to study the cloud forest and its epiphytes (left)

based on these changes. One thing we're doing is carrying out extensive canopy-stripping experiments: physically removing entire communities of epiphytes from experimental trees and leaving control trees intact, and then monitoring the microclimate of the canopy, as well as the water use of the host trees. One of the reasons we're doing this radical experiment is because we want to get a jump on what might be happening in the future.

Are researchers still using the same climbing techniques you helped develop?

They are probably the most common way to get up into the canopy for individual scientists. But there are also aerial walkways people have put in to study bird behaviour. And there's a canopy raft, where you go up in a hot air balloon and then collect samples of leaves and insects through the mesh of the raft floor. But that is only feasible in windless areas that are very flat, so montane cloud forests are not suitable. People also use construction cranes: 17 of them have been installed in forests for canopy research around the world. And now researchers are using drones and satellite imagery, like lidar, which is a kind of radar that allows you to look at the structure of forest from the top as well as down to the forest floor.

You are also a passionate advocate of public engagement. How did that come about?

About 15 years ago, I started hearing chainsaws just outside the boundaries of the reserve where I was working and realised that I need to do more than just writing my scientific papers. I started working with museums, with the National Geographic Society [in Washington DC], but soon realised that this was connecting with people who are already part of the choir. That's when I began thinking about taking these messages further afield.

I began working with faith-based groups, because 80 per cent of the world's population self-identifies as being religious or believing in God. Instead of trying to just push science down the throats of religious people, I decided to read the Bible and the Koran and the Talmud and other religious texts, and pull out all the verses that have to do with trees and forests. Then, I put together a sermon – which I've given at over 40 churches and synagogues and temples – about what I learned from their holy scriptures. For example, there are 328 references to trees and forests in the Old Testament of the Bible, and all of these are about how positive trees are, how important they are for analogies to God, or practical use, or adornments to temples. Who can argue with that!

You have been working in prisons too. Can you tell me about that?

I started by doing a little project that involved the cultivation of mosses, because people in the Pacific Northwest harvest mosses from old-growth temperate rainforest trees and sell them to florists for the horticulture trade. I thought, if we could learn how to cultivate those mosses, that would take the pressure off collecting them from wild places. So I enlisted prisoners as partners to help me.

That was very successful and led to collaborations with conservation groups who had existing ecological restoration projects. We taught inmates how to raise Oregon spotted frogs, from egg to tadpole to adult frog. Then, the conservationist would release them in protected wetland areas. Other inmates did the same thing with Taylor's checkerspot butterflies, with rare species of prairie plants, with a Western pond turtle. So prisons became this model area where inmates were actively contributing to ecological restoration and conservation efforts and getting connected to nature. And that's a very powerful thing to provide for someone whose power has been taken away by being incarcerated.

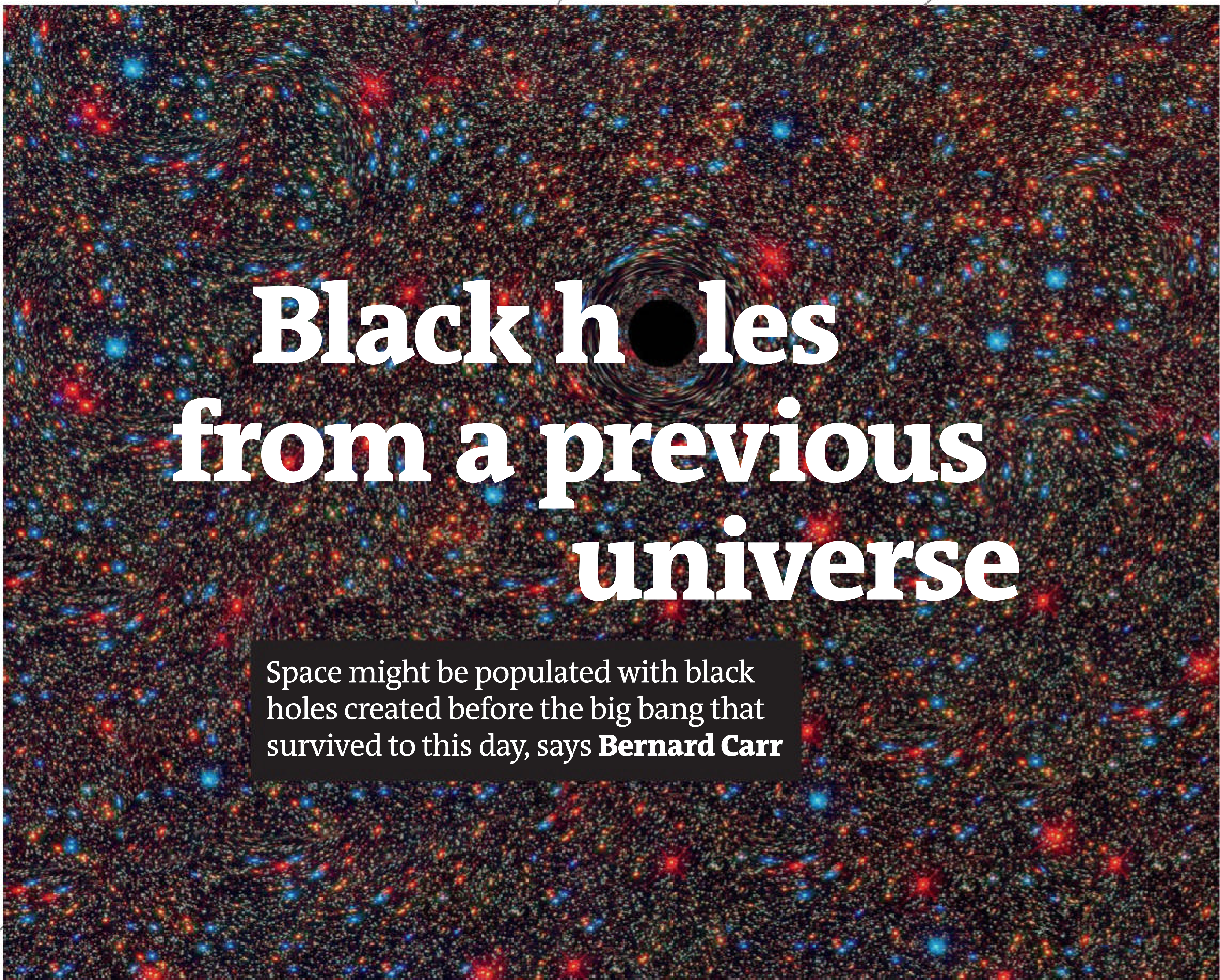
You seem like a very positive person. Does your optimism extend to the future of cloud forests?

Like so many people, I walk a knife ridge between despair and hope when I think about the social and environmental problems we all face. We have to walk really carefully along that line, especially scientists who want to improve how we're protecting forests or using energy. It behoves us to continue with some degree of hope, but always keeping that darkness or despair in our minds, because that is a continuing motivator – at least for me. And I'm not willing to give up yet. ▮



Matthew Ponsford is a London-based journalist who writes The Manuals, a newsletter and how-to guide to ecological engineering

GSFC/NASA



Black holes from a previous universe

Space might be populated with black holes created before the big bang that survived to this day, says **Bernard Carr**



ALMOST exactly 50 years ago, when I was a PhD student, I wrote an article in this magazine about the mounting evidence for black holes, regions of space in which gravity is so strong that light can never escape. Today, there is no longer any doubt about their existence. We know they form from collapsing stars and that supermassive ones sit at the centres of galaxies. We have even taken a picture of two of them. But in my article I also mentioned a more speculative possibility: that smaller black holes might have formed in the early universe, shortly after the big bang.

I was working on this idea under the supervision of Stephen Hawking, who had started to think about such a possibility just a few years earlier. Our work together set the trajectory of my career, much of which has been dedicated to studying what we now call primordial black holes. We still don't know if they formed, but there are good reasons to think they might have. Some of them could still be around today and, excitingly, they could be the answer to a whole range of cosmological conundrums.

Recently, however, I have become interested in an even more exotic possibility: that some black holes could be older than the universe itself. It is a wild idea, but not inconceivable. And new research suggests that we might one day be able to positively identify them, a breakthrough that would radically change our understanding of cosmology.

Most cosmologists would claim that all the matter and energy that permeates our universe today came into existence in a single moment 13.8 billion years ago that we call the big bang. After that, there was a period when the universe grew exponentially fast, called cosmic inflation, before it settled down to a gentler expansion.

One problem with this picture is that we don't know for sure what happened at the big bang. It is often described as a singularity – a point of infinite density – and Albert Einstein's general relativity, our best description of gravity, breaks down at a singularity. As a result, we can't describe it with the usual equations that make sense of reality.

This has led some cosmologists to speculate that the universe started with a big bounce. Instead of everything springing into existence in one moment, a big bounce would be the result of a previous, collapsing universe starting to expand again. This is a kind of big bang, but without a singularity, as the universe always has a finite density. The bouncing scenario is compatible with certain attempts at uniting the laws of physics, such as some models of quantum cosmology, loop quantum gravity and some alternative theories of gravity.

If our universe came from a bounce, it might end in one too. This kind of recurring bounce, where the universe goes through periods of expansion and compression, is called a cyclic universe. It only applies if the universe is destined to recollapse and this, in turn, depends on the nature of dark energy, the mysterious force causing the universe to fly apart faster and faster. Nevertheless, if we found evidence for these bouncing and cyclic models, it would have huge implications, both for how the universe began and how it might end.

Finding this evidence is tricky, partly because everything that would have existed in the previous universe is likely to have been destroyed when it collapsed. Or would it? I think there is a chance that some black holes from a previous universe may have survived the big bounce and still be around today.

The idea that black holes may have formed in the early universe dates to the early 1970s. Stephen and I had been considering whether black holes could form from density fluctuations near the big bang. From our calculations, that did indeed seem possible. ›

But there was a snag. A few years earlier, Russian researchers Yakov Zeldovich and Igor Novikov had shown any black holes formed in the early universe would grow rapidly, reaching an enormous mass today. This was ruled out with observations – we would have seen the effects of such black holes, so they concluded that primordial black holes never formed.

My first paper with Stephen showed this result was wrong. After many days of calculation, I rushed excitedly to his office to give the good news: because of the expansion of the universe, which the pair hadn't considered, primordial black holes wouldn't grow much at all. I was rather deflated to find Stephen had just come to the same conclusion, independently, by doing the calculation in his head. Nevertheless, we agreed: primordial black holes may have existed, after all.

Fifty years later, we still haven't seen any of these black holes for certain, although some people think there are hints of them in detections of ripples in space-time called gravitational waves. What we can say for certain, at least, is that thinking about them prompted Stephen to discover the radiation that black holes give off, which we call Hawking radiation, and the black hole information paradox (see "Black hole candy", right).

Of course, it would be much more interesting if primordial black holes did form, and in recent years there has been a growing interest in the idea. We know that any black holes weighing in at less than 1 trillion kilograms, roughly the mass of a mountain, but the size of a proton, would have evaporated by now because of Hawking radiation. But any black holes bigger than that would exist today.

However, there is an even more intriguing possibility. Around 10 years ago, Alan Coley at Dalhousie University in Halifax, Canada, and I became interested in whether we live in a cyclic universe. We started to consider whether black holes might have formed in a previous cosmic cycle and realised there were two possibilities.

The first is that they formed due to the high density of the previous universe in the final moments of its collapse. This "big crunch" is just like the high-density phase in the big bang, but running backwards in time. So if black holes can form in the big bang, they might also form in the big crunch. In this case, they would have a minimum mass determined by the density of the universe at the bounce, the time at which the universe is at its most dense. If this density is small enough, the black holes could be large enough to potentially explain dark matter, the mysterious stuff that keeps galaxies from flying apart, or the origins of supermassive black holes.

Later work investigated this in more detail. In 2016, Jerome Quintin and Robert Brandenberger, both at McGill University in Montreal, Canada, calculated the quantum and thermal fluctuations of a collapsing universe. They found that black holes can indeed form, albeit only if the universe is dominated by matter, not radiation.

The second possibility is that black holes formed in an earlier phase of the previous universe – just like the black holes that form from the collapse of stars or galactic nuclei in our universe. In either case, our next question was whether the pre-big bang black holes would survive the bounce and persist into the current cycle. This depends on the fraction of the volume of the universe occupied by black holes at the bounce. We reasoned that one could expect black holes to persist if their separation at the bounce was greater than their typical size, because they wouldn't be squeezed together and merge. We concluded that this should be possible in many situations.

In 2015, Timothy Clifton, my colleague at Queen Mary University of London, along with Coley and myself, made a stab at tackling this question in a more mathematically rigorous way. We derived some exact solutions to Einstein's equations of general relativity, describing a regular lattice of black holes in a universe that undergoes a bounce. Our results indicated there are indeed solutions in which

"If black holes can form in the big bang, they might also form in the big crunch"

BLACK HOLE CANDY

Perhaps the most important offshoot from the idea of primordial black holes (see main story) was that it motivated Stephen Hawking to consider the quantum effects of black holes. In particular, he discovered that black holes emit Hawking radiation.

Only primordial black holes can be small enough for this radiation to cause them to disappear in the lifetime of the universe. Thinking about this also led Hawking to the black hole information paradox: quantum theory says information cannot be destroyed, but he argued that information would be lost when a black hole evaporates. He later changed his mind about this and we are still pondering the resolution of this paradox today.

Hawking radiation is one of the most important discoveries in 20th-century physics. It unifies three previously disparate areas of physics: quantum theory, general relativity and thermodynamics. It is such a beautiful result that physicist John Wheeler – who coined the term black hole – once told me that talking about it was like "rolling candy on the tongue".

As Stephen Hawking's collaborator, I was fortunate to have a ringside seat when he was working on these developments. Even if primordial black holes never formed, the discovery of Hawking radiation shows that it has been important to think about them.

multiple black holes persist through a bounce.

Later, we also looked into some cosmological consequences of this proposal, arguing that pre-big bang black holes in different mass ranges could explain dark matter, provide seeds for galaxies and perhaps even cause the bounce itself. In the standard big bang scenario, primordial black holes generated before inflation would be exponentially diluted, so any present today are usually assumed to form after inflation, but there is no inflation in some bouncing models.

Other researchers subsequently elaborated on those ideas. In 2018, Carlo Rovelli at Aix-Marseille University in France and Francesca Vidotto at Western University in Ontario, Canada, investigated the possibility that dark matter is made up of the remnants of pre-big bang black holes. They argued only a tiny fraction of the volume of the universe would be outside these black holes at the bounce, though observers in these regions would see a homogeneous universe at later times.

An even more exotic possibility is that the bounce squeezes the universe so tightly that all the black holes merge. Even the supermassive black holes we know exist today could lead to this situation, if our universe eventually recollapses. These progressive mergers would generate black holes with a hierarchy of increasing mass until, eventually, the whole universe would be turned into a black hole.

Nobody knows what would happen in this situation, but work by two groups has recently thrown light on the problem. Last year, Daniela Pérez and Gustavo Romero at the Argentine Institute of Radio Astronomy and, independently, a team led by Maxence Corman at the Perimeter Institute in Canada, calculated the behaviour of a single black hole during a bounce. Although the details of their calculations differ, both groups agree the black hole could survive through the bounce and that its size may shrink for some period. This shrinking also raises the possibility that black holes may never completely merge.

All of which is well and good, but what about finding evidence? Interestingly, another recent study offers some hope that we might one day be able to identify pre-big bang black holes,



ESA/HUBBLE, DSS, NICK RISINGER, N. BARTMANN

meaning that we could distinguish them from black holes formed in our universe. It was led by Yi-Fu Cai at the University of Science and Technology of China, who is interested in the idea that primordial black holes might have generated the supermassive black holes at the centres of galaxies.

Too big, too fast

These huge black holes range from 1 million to 10 billion times the mass of the sun. We know from looking at the distant universe that they already existed very early on – possibly too soon for them to have been created by standard astrophysical processes. It isn't clear how they could grow so big, so fast. One possibility, although not the mainstream view, is that they were seeded by primordial black holes. In which case, is there some way to figure out if these primordial black holes came from a big bang or a big bounce?

Cai and his colleagues modelled the density fluctuations in the inflationary and bounce scenarios, to compare the two models. They predict that the number of supermassive black holes would fall off more steeply with increasing mass in the case of a bounce. At the moment, we don't have enough data to discriminate between the two scenarios. But future observations by the James Webb Space Telescope could provide this.

We're not certain how supermassive black holes formed

The existence of primordial black holes formed in this universe is speculative, so the notion of black holes from a previous universe might seem doubly speculative. Nevertheless, it is important to explore this possibility, not to mention exhilarating. Just as thinking about primordial black holes has led to important insights into quantum gravity, thinking about pre-big bang black holes may lead to further physical insights, even if it turns out that the universe isn't cyclic.

I have recently retired, and I find it strangely appropriate that my career, which began with the study of black hole formation at the start of this universe, is finishing with the study of their formation at the end of the last one. My article 50 years ago concluded that "black holes are as pervasive in theory as they are evasive in observation", but I am now more optimistic about finding primordial black holes, whether or not they formed in a previous universe. ∎



Bernard Carr is emeritus professor of mathematics and astronomy at Queen Mary University of London

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Stargazing at home

At the heart of the Crab

Nestled in the constellation of Cancer, the Beehive cluster is tricky to find, but these stars are worth the effort, says **Abigail Beall**



Abigail Beall is a feature editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

What you need
Binoculars or a small telescope

SOME constellations force you to look at them. Their brightest stars are so clear, even in a night sky full of light pollution, that they draw you in. Others sit there quietly, waiting for you to find them.

This week, we are looking for one of the latter. Cancer is a humble constellation, nestled in between its louder neighbours Gemini and Leo. Without any particularly bright stars of its own, Cancer is the faintest of all the zodiacal constellations, which makes it tricky to find. But once you have spotted it, there will be something beautiful waiting for you: the Beehive cluster (pictured right).



STEVEN MILNE/ALAMY

Cancer is visible from all over the world, and April is a great time to see it. Start by locating three bright stars: Regulus in Leo and the twins Castor and Pollux in Gemini. To find Castor and Pollux, first find the three stars in Orion's belt. From there, look for the blueish white Rigel in Orion's right foot and the red giant in Orion's left shoulder, called Betelgeuse. Draw a line from Rigel through Betelgeuse and continue that line until you see two bright stars. These are Castor and Pollux.

Next you need to find Regulus, the brightest star in Leo. You can do this using Procyon, which is the brightest star in Canis Minor. If you are in the northern hemisphere, then Gemini will be sitting above Orion, and Procyon will be to the left of the two of them. If you are in the southern hemisphere, Gemini will appear below Orion, and Procyon will be to the right. Either way, draw a line from Rigel to Procyon, then continue this until, if you are in the northern hemisphere, you see a bright star nestled at the bottom of what looks like a question mark. In the southern hemisphere, it will be an upside down question mark. This bright star is Regulus.

Now you have found Leo and Gemini, look directly between the two. The faint, upside-down Y, as seen in the northern hemisphere, is Cancer; in the southern hemisphere, it looks like a normal Y. In a brightly lit area, you won't see much in this patch of the sky, but if you have dark skies and little moonlight, you will be able to make out the Beehive cluster.

Sitting at the centre of Cancer, this is one of the brightest open star clusters – a group of young stars that all formed from the same cloud of gas and dust – in the night sky, containing about 1000 stars. Like the Pleiades and the V-shaped Hyades in Taurus, the Beehive cluster is about 600 million years old, and astronomers think it is possible all three formed from the same cloud of dust.

With the naked eye, the Beehive cluster looks like a fuzzy blob about 1.5 times the size of the full moon. But use binoculars or a telescope and you will see lots of beautiful stars. In fact, this cluster was one of the first bits of the night sky Galileo observed with his telescope, in 1609. ■

Stargazing at home appears every four weeks. Share your stargazing successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistStargazing

Next week
The science of gardening

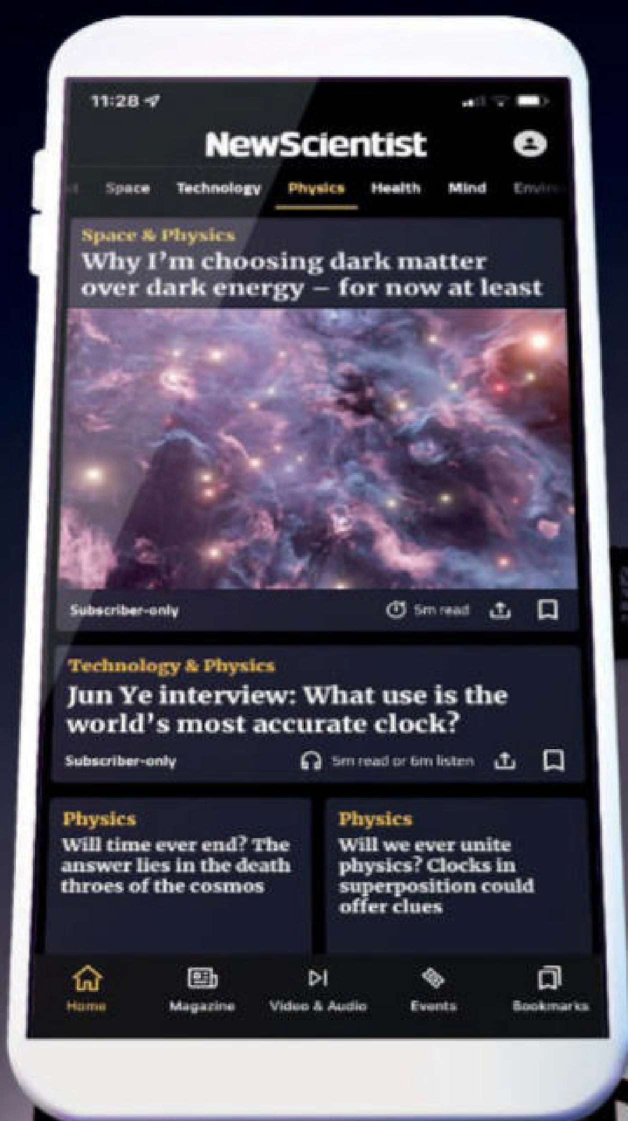
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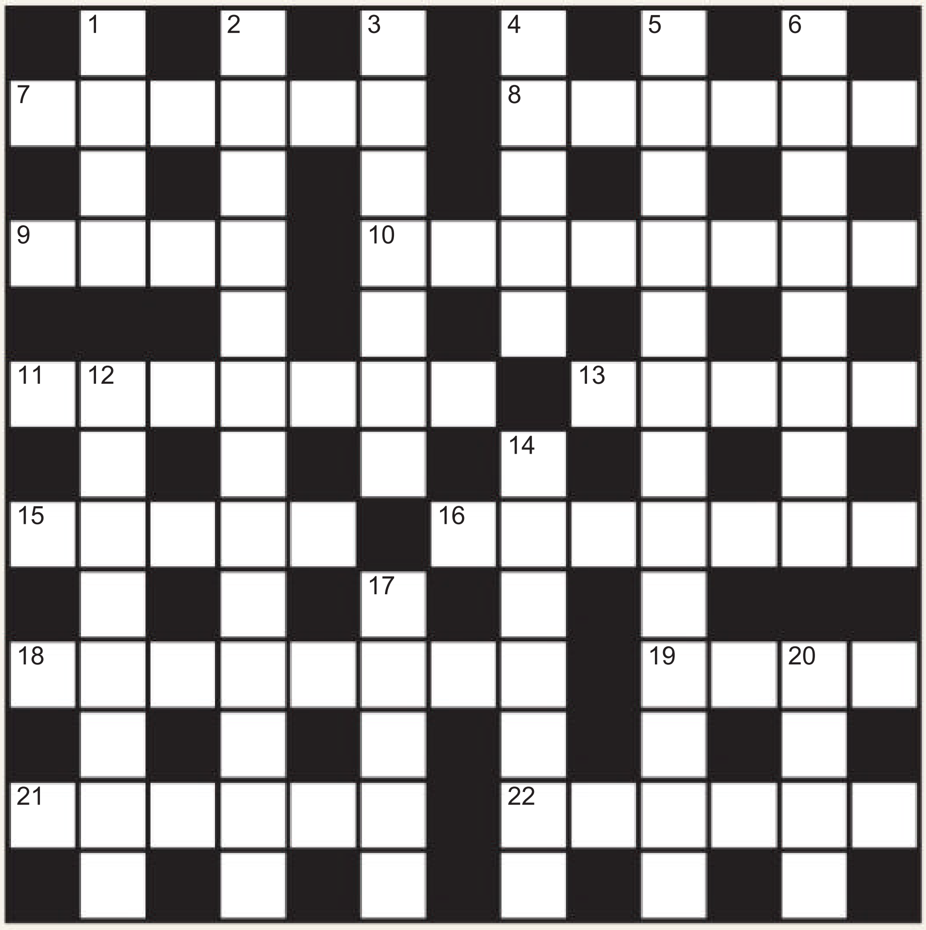
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Cryptic crossword #106 *Set by Wingding*



Scribble zone

Answers and the next quick crossword next week

ACROSS

7 Parts of beetles kept by retired party leader (6)
8 Nauseating reference writer recalled (6)
9 Round rodent returned to get vegetable (4)
10 Rooms in submarines where mutated coral is absorbing potassium (8)
11 Complicated head teacher went fishing (7)
13 Drug found in urine collected by steward on vacation (5)
15 Gather army for an audience (5)
16 Fish and lion in experiment (7)
18 Bromine in wheat, perhaps affecting the brain (8)
19 Killed a great number (4)
21 Two goats upset antelope (3-3)
22 South American animal gets cystitis after one move (6)

DOWN

1 Bloodsucker starts to frustrate law enforcement agents (4)
2 Extremely ardent turtles in disagreement (2,11)
3 Large mammal spread out, top to bottom (7)
4 Unusual dam on top of dyke (5)
5/6 Omicron spike sends cases all over the place (forget alpha!) – it's a painful condition (13,8)
12 Ox in area treated for eating disorder (8)
14 Genuine fish material used in fireworks (7)
17 Rook in birthday treat for wetland bird (5)
20 Young amphibians initially eat fish, then slugs (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #195
set by Bethan Ackerley

1 What name is given to the wave-like contractions that move food through the digestive tract?

2 What is the only sea without a coastline?

3 What colour flame is produced when potassium is burned?

4 The hair-like appendages that protrude from human sperm cells are known as what?

5 In what year did the first crewed flight in space take place?

Answers on page 55

Puzzle
set by Zoe Mensch

#215 Trivia Tuesday

The team members were assembled for their regular meeting with their eccentric manager.

"Before we get to the main agenda, we'll observe our weekly 'Trivia Tuesday'. Today's trivia titbit is that the month and day are the same number. It is 4 April, which is the fourth day of the fourth month. How about that?"

The rest of the office rolled their eyes. "Seems like the boss forgot until the last second again," whispered Grace. "I guess he just got lucky with the date."

Clancy thought for a moment. "Sadly, it isn't the only time this year when he'll be able to use the same kind of 'trivia' for Trivia Tuesday."

Without looking at a calendar, can you work out how many more Trivia Tuesdays after 4 April will fall on the nth day of the nth month?

Solution next week

In bad taste

How was rhubarb found to be edible? It certainly isn't palatable raw.

Chris Robinson
London, UK
As a child in the north of England, I was often kept quiet with a stick of rhubarb and a saucer of sugar: dip and bite. I imagine that the many periods of starvation in human history expanded the boundary of what is considered edible.

Robert Bernstein
Santa Barbara, California, US
In rural Connecticut as a child, our farmer neighbour gave me some of her raw rhubarb and I was delighted at the tart flavour. I only stopped eating rhubarb later when I found out that its oxalic acid can have some harmful effects.

What "isn't palatable" for one person may be delicious to another. The mystery to me? How anyone can think that bitter cilantro (coriander) or kale belongs in food.

"My guides in Pakistan were amazed when I cooked rhubarb into a crumble, as they ate it raw and hadn't heard of it being cooked"

***@asifhaidari24**, via Twitter*
Rhubarb grows wild in Afghanistan. There are two types, one called *rawash* and the other called *chukri*. It is very tasty and is a good source of vitamin C.

***@PostgradSlave,** via Twitter*
Rhubarb is one of the first crops of early spring with a high vitamin C content. It was very important before fruit was imported.

Andy Maloney
Wellington, New Zealand
When I was travelling in the Karakoram mountains in northern Pakistan, I found rhubarb growing wild. My guides called it "sporth" and ate the stems raw. They were amazed when I cooked the stems into a rhubarb crumble, as they had never heard of it being cooked.

The raw stems had a pleasant, tart acidity, though were only consumed in small quantities – presumably due to their oxalic acid content.

Jessica Hudson
Rare books librarian at the Royal Horticultural Society Lindley Library, London, UK
Historically, rhubarb was associated with medicine. Ancient Greek physician Pedanius Dioscorides advocated the use of the root for stomach complaints and as a liver treatment, and it has been used in traditional Chinese medicine for centuries.

The earliest work dedicated to rhubarb and its medicinal qualities held in the RHS Lindley Library is the 1679 book *Rhabarbarologia* by German physician Mathias Tiling. In 1792, Scottish physician William Fordyce wrote a treatise on the importance of the cultivation of rhubarb in England and noted that it was a cure for the luxurious excesses of the rich upper classes.

By the 1700s, the stems came into culinary use in England, but were being eaten as food far earlier in Italy and other European countries. Rhubarb was often used as an alternative to gooseberries and its increase in popularity was linked to the greater availability of sugar at the time.

Cooks experimented by using different parts of plants that were known to be medicinal through trial and error. In 1758, a cook at the Palace of Versailles in France allegedly used rhubarb leaves in a soup, unaware of their toxicity, but there are no records of what happened to the unwitting diners.

A 1739 letter sent to the Americas included a recipe for a rhubarb tart, and an early example of rhubarb in a printed recipe is in *The Compleat Confectioner; or, Housekeeper's Guide* by Hannah Glasse (1760), when rhubarb's use as food began to surpass its use in medicine.

[Ed. – Rhubarb contains oxalic acid, which is poisonous at high doses, though the majority is in the leaves and these aren't usually eaten. However, rare cases of poisoning due to excessive consumption of rhubarb stems have been reported.]


STEVE WILLIAMS

What caused these ice patterns to form on a pane of glass – Jack Frost, perhaps?

This week's new questions

Frosty formations **Why did these strange ice patterns form on a glazed door (pictured)? They don't appear on other glass from the same source.** ***Steve Williams**, Honing, Norfolk, UK*

Racing ahead **Are racehorses aware that they are expected to come first or are they just responding to the frantic urges of the jockey?** ***John Spencer**, Sydney, Australia*

Wonky weather

How would global weather patterns change if Earth were to rotate in the opposite direction?

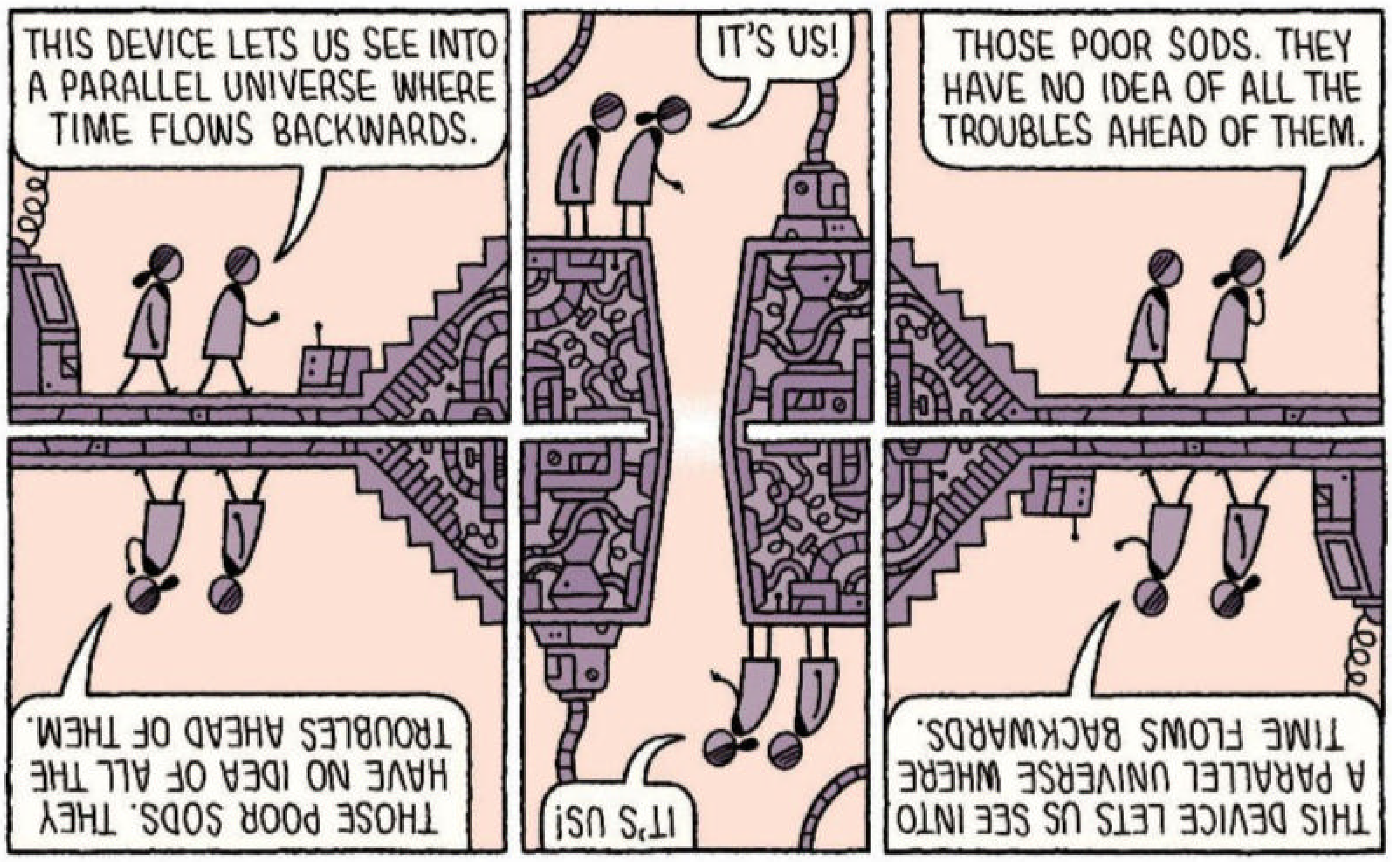
Nick Canning
Coleraine, County Londonderry, UK
Local weather is produced by the interaction of landmasses with the air and sea currents that transport heat and water. Changes in these flows would profoundly alter the weather, resetting the climate on each continent. Patterns of arid versus verdant land would change across the world.

On an Earth with reversed spin, the direction of Coriolis forces – the deflection of air movements to the right in the northern hemisphere and left in the southern due to the spin of Earth – would reverse. So wind circulation around low-pressure zones would reverse from anticlockwise to clockwise in the northern hemisphere (and vice versa in the southern hemisphere).

The jet stream would reverse direction, so weather fronts would travel from east to west over Europe, reducing the annual rainfall in the UK. Thermally

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Tom Gauld
for New Scientist



driven sea currents north of the equator would change direction from north-east to north-west, disrupting the Gulf Stream and making the UK colder in winter.

A 2018 simulation of the climate of a counter-rotating Earth indicates that the tropics would remain warm and humid, deserts would form mainly in the Americas and would no longer dominate North Africa and the Middle East, and western Europe would become much colder.

Mike Follows
Sutton Coldfield, West Midlands, UK

One of the most obvious manifestations of weather patterns is the associated winds, caused by air moving from high to low pressure. If Earth rotated in the opposite direction, it would lead to prevailing winds reversing. So, instead of western Europe and the eastern seaboard of the US experiencing westerlies, these regions would be subjected to easterlies. The regional climates would probably swap over too,

"Earth and its history would be very different if the rotation of the planet was in the opposite direction"

such that western Europe would have a more continental climate and cold winters, while the eastern US would have a more maritime climate and might have warmer winters.

Graham Smith
Werribee, Victoria, Australia

If a uniform Earth rotated in the opposite direction, there would be little change in the north/south components of the winds, which are largely driven by temperature differences. However, all of the east and west wind components would be reversed. For example, the south-east trade winds would become south-west trade winds at the same latitude.

However, Earth isn't a uniform ball. A continent in a very large ocean would experience reversed east-west climate. For example, the south-east trade winds bring rain to the east coast of Australia, which mostly drops on the mountains of the Great Dividing Range along the east coast. The water quickly flows back into the sea, leaving arid land on the west side of the mountains. In a reverse-rotation world, the south-west trade winds would bring rain to Western Australia, which would penetrate much further inland because there are no significant mountain ranges for several thousand kilometres.

It is harder to predict the effect on the northern hemisphere because the continents cover much more of the surface area. However, the Indian monsoon currently comes from the south west. In the alternate-rotating world, the monsoon from the warm waters of the Indian Ocean would come from the south-east and dump on the Arabian Peninsula instead of India.

Earth and its history would be very different if the rotation of the planet was different. ▮

Answers

Quick quiz #195
Answers

1 Peristalsis
2 The Sargasso Sea
3 Lilac
4 Flagella
5 1961

Quick crossword #129 *Answers*

ACROSS 1 Quicklime, **6** Lilac, **9** Orionid, **10** Pump out, **11** Add N To X, **12** Yardarm, **13** Corncrake, **15** Kudzu, **16** Mower, **19** Coagulant, **22** Rib cage, **23** Mustela, **25** Density, **26** Galileo, **27** Early, **28** Eccentric

DOWN 1 Quota, **2** I-girder, **3** Kinetic, **4** Index, **5** Emphysema, **6** Lamarck, **7** Leopard, **8** Catamount, **13** Cambridge, **14** Archetype, **17** Webinar, **18** Reality, **20** Upsilon, **21** Areolar, **23** Magic, **24** Azoic

#214 Seven up!
Solution

The number is 7630.

Call it ABCD. BCD is divisible by 7, and since ABCD is also divisible by 7, A can only be 7. Similarly, since ABC is divisible by 7, there can be no remainder when D is divided by 7, so D can only be 7 or 0 – and 7 is already ruled out as no digit is duplicated. The number BC must therefore also be a multiple of 7, i.e. 14, 21, 28, 35 etc. The sum of the digits in the number that is made by adding all digits of the code is only 7 if B and C are 6 and 3: In other words, 7+6+3+0=16, and the digits 1+6=7.

Nihilism and hypergunk

Irreducibly collective existence and bottomless nihilism aren't for everyone. Or maybe they are. Jonas Werner, a philosopher at the University of Bern, Switzerland, published a crisp, perhaps irresistible, 16-page-long jotting called "Irreducibly collective existence and bottomless nihilism".

The matter isn't as simple as some people assume. Nor are some of its concepts, though they have colourful names. "Gunky objects", for instance. Gunky objects, says Werner, are "objects such that every part of them has a proper part". Gunkiness has to do with how-many-ness. How-many-ness is seldom simple. Werner explains: "There are distinctions between countable gunk (a gunky object that has not more than countably many non-overlapping parts), gunk of higher cardinalities, and hypergunk." Hypergunk is a variety of gunk that possesses particular mathematical qualities.

Parts of the philosophy community have enjoyed arguing about hypergunk since before the turn of the most recent century. Patrick Reeder, at Kenyon College in Ohio, is a philosopher who not only appreciates hypergunk, but has also tried to make it easier for everyone to appreciate hypergunk. He wrote a simple guide called "Quick and easy recipes for hypergunk".

Reeder's guide includes a provocative statement, which Feedback alas lacks space to explain properly here. So let us let Reeder's words stand on their own, and let us hope those words provoke you, dear reader, to pursue what they might mean for you personally: "Given the cost of hypergunk for theories of possible worlds, this is meant to raise the stakes for those eager to dismiss hypergunk as mere metaphysical decadence."

Twisteddoodles *for New Scientist*



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Nasal warfare

There is a war going on in your face. To be bluntly specific about it: there is bacterial warfare in the nasal cavity.

Britney Hardy and D. Scott Merrell at the Uniformed Services University of the Health Sciences, Maryland, write about it in the *Journal of Bacteriology*. They sketch the micro-military history of the clash: "bacteria that live in the nasal cavity have evolved a variety of approaches to outcompete contenders for the limited nutrients and space; broadly speaking, these strategies may be considered a type of 'bacterial warfare'."

Hardy and Merrell describe the territory over which the skirmishes rage: sun-deprived landscapes replete with battlefields that are rugged and often simultaneously slippery, sticky, wet, gooey and gross. The middle meatus, for one, "comprises a network of bone and mucosal folds and is also home to mucin-secreting goblet cells that are responsible for the production of the mucus that lines the nasal cavity".

They point out that, as with almost any war, careful study of this ceaseless, dreary clash presents opportunities and hopes, both biomedical and commercial. "A greater molecular understanding of bacterial warfare has the potential," they enthuse, "to reveal new approaches or molecules that can be developed as novel therapeutics."

Pop science

"Where do our music preferences come from?" ask Alexandra Lamont at Keele University and Jessica Crich at the University of Sheffield, both in the UK. Mostly, they find, from our families: one way (directly) and another (our family's reaction to our telling them about whatever new music we encounter). But Lamont and Crich mostly avoid a related question: when do our music preferences stop growing and become calcified?

Upon reaching adulthood, many people stop paying much attention to new popular music and performers. Successive generations of middle-aged people showed uninterest in the music of new kids on the block Elvis Presley, Taylor Swift, Lil Baby and others.

A study done 10 years ago makes the case that musical-taste calcification sets in early – if you are strongly right-handed. Stephen Christman at the University of Toledo, Ohio, made that discovery by having 92 students answer a survey about their handedness and their musical likings. Christman's paper says that right-handers have less "open-earedness" than other-handed people.

David Hargreaves and Arielle Bonneville-Roussy at the University of Roehampton, UK, tried to refine the notion of open-earedness. (They ignored the handedness angle.) In a report called "What is 'open-earedness', and how can it be measured?" they take an open-minded approach to open-earedness. They propose a subtle blend of four definitions that, if considered together, "provide a richer and more nuanced concept of open-earedness than hitherto". One definition involves a measure with the alluring name "the Osnabrück Open-Earedness Index".

Bonneville-Roussy – working with Tuomas Eerola at Durham University in the UK – has also found evidence that many adults, while ignoring new pop music, become interested in classical or other musical genres. This broadening of interest, they say, perhaps continues "throughout the entire lifespan". By these lights, interest in Presley, Swift or Baby may roll over into interest in Ludwig van Beethoven, Miles Davis or Anna Netrebko. Thanks to this finding, we can be open-minded to the happy prospect of being open-eared even as age besets us.

Marc Abrahams

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